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The power of treaties

International weapons conventions may not be perfect, but they are a vital mechanism for making wars less barbaric and less frequent — a cause that should galvanize scientists and others.

The apparent use of sarin to kill more than 1,400 civilians in Damascus on 21 August may highlight the limits of the Chemical Weapons Convention (CWC) — but that does not mean that the world can afford to turn its back on such treaties.

The role of international treaties in restricting the proliferation of nuclear, chemical and biological weapons has not had a good press in recent years. Conventional wisdom tends to scorn the value of such 'pieces of paper' in real politick. Critics from both the left and the right heap derision on their selective reach and implementation.

Yet these treaties are crucial to everyone who is interested in making wars less barbaric and less frequent. Pieces of paper they may be, but large powers adhere to their contents with care, as do the smaller ones who crave international respectability.

As Hans Blix, the former chief United Nations weapons inspector, has pointed out, even regimes that are regarded as political outliers are highly sensitive to treaty adherence. That is why, for example, North Korea withdrew from the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 2003, before resuming its nuclear-weapons programme. It is also why Syria is one of just seven countries (including Egypt and Israel) not to join the CWC.

These treaties also matter to scientists, or ought to, because only scientists have the technical expertise and institutional basis to devise their content and implementation. That is not true of diplomats or soldiers, or of other parties, such as the unfortunate victims of chemical weapons in Syria. As the US physicist Herbert York said of his peers' role in the development of the first, limited nuclear test-ban treaty half a century ago: if not us, who?

The CWC has its origins in the 1925 Geneva Protocol, which held the use of chemical weapons to be illegal. Since it came into effect in 1997, the CWC has been a considerable success, with its secretariat supervising the destruction of some 78% of known chemical-weapons stocks in signatory nations — a figure that is expected to reach 99% by 2017.

Three questions will remain after that milestone is reached: what to do about non-signatories; how to deal with non-state actors; and how to extend the CWC's progress to the problematic field of biological weapons.

The position of non-signatories, at least, should become less tenable. As this group diminishes in number, precedent suggests that the terms of the treaty are likely to become accepted as international law, opening violators up to possible criminal prosecution. It is not unreasonable to hope that pressure on non-signatories will eventually bear fruit.

Non-state actors — terrorists among them — have never really fallen under the remit of treaties. However, the CWC does include provisions, thus far never invoked, for 'challenge inspections' to be conducted when weapons violations are suspected. It is conceivable that such inspections could be used if non-state actors were suspected of stockpiling chemical agents.

The last question regards the relationship between the CWC and its older but weaker cousin, the Biological Weapons Convention (BWC). The CWC office has several hundred staff in The Hague in the Netherlands, but the BWC has only a tiny secretariat in Geneva, Switzerland — and no verification regime. That is partly on account of long-standing US resistance to the idea: because biological agents grow or die, they are hard to inventory, and sceptics contend that a verification regime would result in an orgy of commercial larceny.

"International treaties ... are more true to the cause of peace than a fusillade of cruise missiles."

One suggestion is to merge the two (see L. K. Sydnes *Nature* **496,** 25–26; 2013) and adapt the CWC's powerful verification infrastructure to tackle the BWC's mission. But diplomats are sceptical that two international treaties could ever be successfully merged. What is clear is that biologists — whose international representation is more fragmented than that of chemists or physicists — could work harder towards the augmentation of the BWC, and the eventual development of a verification regime.

In the meantime, large political powers need to be less selective in their pursuit of disarmament treaties, and more forthcoming in providing the resources necessary for their implementation. It is hard for Britain and the United States to strengthen the CWC, for example, while they continue to drag their feet in implementing their existing nuclear obligations under the NPT.

International treaties, in the end, will never be entirely fair, or equitable, or implemented consistently. They are nonetheless more impressive than the barrage of platitudes that passes for political discourse on international security — and more true to the cause of peace than a fusillade of cruise missiles. The BWC, CWC and NPT are all imperfect but they are the instruments that we have in our hands. They can each play a part in making war less likely, as well as less ghastly. ■

Nuclear error

Japan should bring in international help to study and mitigate the Fukushima crisis.

The radioactive water leaking from the site of the wrecked Fukushima Daiichi nuclear power plant in Japan is a stern reminder that we have not seen the end of the world's largest nuclear crisis since the Chernobyl meltdown in Ukraine in 1986. After an earthquake and tsunami crippled the Fukushima plant in March 2011, it became clear that efforts to decontaminate the area would be long-lasting, technically challenging and vastly expensive. Now it turns out that the task has been too big for the owner of the plant, the

Tokyo Electric Power Company (TEPCO). The Japanese government on 3 September announced a plan to take over the clean-up, but its intervention is overdue.

In the two and a half years since the accident, TEPCO has repeatedly failed to acknowledge the nature and seriousness of problems with safeguarding nuclear fuels in the three destroyed reactors at Fukushima. Each day, some 400,000 litres of water are being funnelled into the reactor cores to prevent the rods from overheating. Only in recent months has TEPCO admitted that some contaminated water is leaking into the reactor basement and, through cracks in the concrete, into the groundwater and the adjacent sea. Few independent measurements of radiation exposure are available, and it is worryingly unclear how these leaks might affect human health, the environment and food safety. But the problems do not stop there. There are now almost 1,000 storage tanks holding the used cooling water, which, despite treatment at a purification system, contains tritium and other harmful radionuclides. The leaks make clear that this system is a laxly guarded time bomb.

It is no secret that pipes and storage tanks sealed with rubber seams have a habit of leaking. TEPCO's reliance on routine patrols to detect any leaks has been careless, if not irresponsible. That the company, in response to the latest incidents, intends to refit the tanks with sensors and extra safety controls just underlines the makeshift way in which the storage facilities were set up in the first place. Meanwhile, the fate of the constantly amassing polluted water is undecided. Proposals earlier this year to dump it into the sea understandably met with fierce opposition from local fisheries.

Given the government's past actions and information policies, one might doubt whether it would be any more competent than TEPCO at managing the situation and communicating it to the public. Over the weekend, it turned out that radiation doses near the leaking tanks are 18 times larger than first reported: leakage that started as a mere 'anomaly' has turned into a genuine crisis. Japan should start consulting international experts for help. The United States, Russia, France and the United Kingdom — to name but a few — all have know-how in nuclear engineering, clean-up and radiation health that would serve Japan well. An international alliance on research and clean-up would help to restore shattered public trust in the usefulness and effectiveness of monitoring and crisis-mitigation.

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The most important impacts of the leaks will be those on the sea off Fukushima and the larger Pacific Ocean, which must be closely monitored. After assessments by US and Japanese scientists in 2011 and 2012, two major questions remain unanswered. How much radioactivity is still entering the sea? And, given the high levels of radioactivity that have been measured in some species long after the accident, when will fish and seafood from the region be safe to consume? The leaks make it more urgent to find answers to these questions.

To make reliable assessments of any environmental effects, scientists need to be able to collect data on contamination of marine food webs with all long-lived radionuclides, and particularly with caesium-137, strontium-90 and plutonium-239. They also need to know the sources of contamination, and to study the transport of radionuclides in groundwater, sediments and ocean currents. Current Japanese Prime Minister Shinzo Abe and his government have promised to boost science; they should encourage and support researchers from around the world in collecting and sharing information. Chernobyl was a missed opportunity for post-accident research — in that sense at least, Fukushima could do much better. ■

The nitrogen fix

A simple iron complex offers a chance to update how the global supply of ammonia is made.

When it comes to the natural processes of plants, photosynthesis tends to hog attention. If researchers could efficiently copy the ability to convert sunlight to energy, chemists promise, our energy problems would be over. They have not managed it yet.

They have had more luck with harnessing and mimicking the less-heralded, but just as important, process of nitrogen fixation — the conversion of nitrogen from the air into ammonia, which can be used by plants to make DNA, RNA and proteins, and by industry to make fertilizers and explosives. On page 84, chemists announce the discovery of an important piece of the puzzle. Jonas Peters and his colleagues at the California Institute of Technology (Caltech) in Pasadena have identified a small iron complex that efficiently catalyses the conversion.

The discovery comes a full century after the chemist Carl Bosch opened his nitrogen works in Oppau, Germany, and in doing so sealed the deaths of millions of people, and the birth and survival of billions more. Bosch had worked out how to scale up a laboratory reaction to combine nitrogen from the air and hydrogen from natural gas into synthetic ammonia. Textbooks talk about the Haber process, named after German chemist Fritz Haber, who made the theoretical breakthrough, but it is more properly called the Haber–Bosch process. Both Haber and Bosch won Nobel prizes for their work.

It is hard to overstate the impact of the Haber–Bosch process. A figure published in 2008 (the centenary of Haber's patent) shows how the increase in world population since 1960 has kept step with increases in the use of nitrogen fertilizer (J. W. Erisman *et al. Nature Geosci.* **1**, 636–639; 2008). Population growth through access to fertilizer and therefore food was one of Haber's goals in developing his process. The other was to give Germany mastery of the science of munitions. Both goals demanded that the industrial supply of fixed nitrogen grew from the few hundreds of thousands of tonnes available per year at the start of the twentieth century, when it relied on natural resources such as guano and mineral saltpetre (potassium nitrate and sodium nitrate).

Bosch had to treat nitrogen and hydrogen under massive pressure and heat to make the conversion to ammonia. In industry, the process is still done in the same expensive and energy-intensive way.

Crucially, the synthesis described by the California group unfolds under mild, environmentally friendly conditions, just as it does in nature. (Well, when the conversion is done in the soil — another way to fix nitrogen naturally is through the searing flash of a lightning strike.) Peters and his colleagues examined the enzymes and cofactors that make ammonia among the roots of plants such as legumes. Iron has for decades been known to be important in these cofactors, but exactly how and why have been a mystery. For a while, attention switched to molybdenum, which chemists showed could also help to make ammonia, but biochemical and spectroscopic data have renewed the focus on iron. The finding from the Caltech scientists supports this: the iron complex they identify can do the job with no need for molybdenum.

It took less than five years for Bosch to commercialize Haber's discovery, and to revolutionize the industrial supply of ammonia. It will probably take longer for researchers to build on the latest work, but at least now they have a platform.

The stakes have always been high. In the nineteenth century, Peru and Chile fought a war over guano. When Germany was denied access to Chile's saltpetre during the First World War, the Haber–Bosch process gave it — and the world — an alternative, which it grasped with both hands. All the time, legumes such as alfalfa, peanut and clover have been quietly and efficiently doing their thing. A century after Bosch, they could help to write a new chapter in the ammonia story. And photosynthesis? Watch this space. ■

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