that are not only more effective but also more equitable. By actively involving scientists from Africa in the field of green chemistry, the scientific community can tap into a broader spectrum of ideas and approaches, leading to more robust and sustainable outcomes.

The underrepresentation of these groups in green chemistry highlights systemic inequities across STEM fields. Addressing these disparities is not just a matter of social justice but is also crucial for tackling global environmental challenges. Issues such as climate change, pollution, and resource depletion disproportionately impact developing regions, including many African countries. By involving African scientists in green chemistry research, one can ensure that solutions are tailored to the specific needs and contexts of these regions, bridging the gap between global and local strategies. This approach is essential for sustainable development, as it empowers local communities to address their environmental challenges independently, without relying solely on external expertise.

This shift toward inclusivity is not only about fairness but also about improving the quality and relevance of scientific research. A more diverse scientific community is better positioned to tackle the interconnected challenges of the 21st century, from climate change to environmental justice. By ensuring that scientists from Africa have a seat at the table, green chemistry can become an even more powerful tool for positive global change.

To advocate for and support this vision, a coalition of experts is organizing the IUPAC-backed African Training School on Green Chemistry and Environmental Sustainability (GreenChemAfrica), took place from 21-27 April 2024, at Mohammed VI Polytechnic University (UM6P) in Morocco. This landmark event—the first of its kind in Africa gathered 27 lecturers and 54 participants from 15 African countries, with a gender ratio of 54 % female and 44 % male, marking the beginning of a continent-wide movement in green chemistry.

Designed to foster an interactive yet informal learning environment, the program will facilitate exchanges between African graduate students and early-career scientists and leading global experts in green chemistry. The event provided a comprehensive overview of how interdisciplinary and multidisciplinary approaches, supported by international collaboration, can address contemporary challenges in green chemistry and sustainable processes. Topics covered included green (in)organic synthesis, green solvents, eco-extraction, sustainable (bio)chemical processes, biotechnologies, synthetic biology, biorefinery, and the application of life cycle assessment.

The next edition of this school will be held in Benguerir, Morocco, from 20-25 April 2025.

https://susmat.um6p.ma/greenchemafrica-2024/

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New Perspectives on the Fight against Chemical Weapons

by Greta Heydenrych

The worldwide fight against chemical weapons is governed by the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction, usually referred to as the Chemical Weapons Convention (CWC). The CWC is administered by the Organisation for the Prohibition of Chemical Weapons (OPCW), which has its seat in The Hague, Netherlands.

OPCW and the Chemical Weapons Convention

The CWC, which entered into force almost 30 years ago, on 29 April 1997, is a sterling example of multilateral international collaboration, and has been signed and ratified by all but four of the United Nations member states—193 countries in all. The CWC obliges its state parties to prohibit the use of chemical weapons and to prohibit their manufacture, development, transport and stockpiling. Another obligation is the declaration of stockpiles and their destruction. The state parties must allow OPCW inspectors to verify chemical weapons' destruction and must permit OPCW inspectors to conduct regular inspections of sites that might be used to manufacture chemical weapons, their precursors or any chemical that may have a dual use. In this context, it is important to note that the OPCW is not an enforcement agency. It can, at the behest of one or more state parties, conduct a fact-finding investigation upon suspected use of chemical weapons and present its findings to the state parties. The barrier to such an investigation is high, as verifiable proof is required. Moreover, an investigation can be blocked by a 75% majority of the state parties.

So, how successful is the CWC? As of 31 August 2024, 100% of the chemical weapons stockpiles declared by possessor States have been verifiably destroyed. As usual, the devil is in the details—here, the word "declared" and the meaning of "chemical weapon." It is quite likely that not all stockpiles are declared, and there could be many reasons for this. It could be that they simply are awaiting discovery, that not all state parties are completely forthcoming about potential chemical weapons on their territories, or that non-state actors gained access to stockpiles before these could be declared. Secondly, although the CWC clearly defines three classes of controlled substances, not all chemicals that are harmful or toxic are covered by the Convention. One notable example is chlorine gas, which is not listed as a chemical weapon, but can be used as such. To circumvent such dual use, the CWC does forbid the use of any toxic chemicals for the exclusive purpose of causing harm to humans.

This leads us to the third reason why the success of the CWC should not be taken for granted. The accelerating development of artificial intelligences (AIs) of various flavours changes how we should look at the Convention and its implementation. For this reason, the OPCW has initiated a series of meetings and discussions centred around the theme of AI and the CWC. A key event has been the Global Conference on the Role of Artificial Intelligence in Advancing the Implementation of the Chemical Weapons Convention, which was hosted by the Kingdom of Morocco in its capital, Rabat, on 22-24 October 2024. The meeting aimed to bring together AI experts, policy makers and diplomats to share perspectives on the opportunities offered by AI, as well as potential risks, in the context of the CWC's implementation.

The three overarching themes were *AI and chemistry*, *Challenges and opportunities for chemical industry* and *Counterterrorism and its impact on advancing the CWC's implementation*. About 50 experts were invited

to give their perspective in presentations and panel discussions on subtopics grouped together under the three themes.

AI and chemistry

The most important message that came from this theme is that openly accessible AI-driven retrosynthesis applications can enable people with limited chemistry knowledge to synthesise chemicals that up to now could only be made by professional experts in chemical synthesis. This represents a clear threat, as it opens the door to terrorist organisations and other non-state actors to easily access chemical weapons and toxins. On the other hand, it could also enable quicker and easier response to victims of chemical attacks as these same tools could be used to synthesise life-saving treatments.

Another aspect to keep in mind is that today's AI models depend critically on the quality of the data with which they are trained, and that some human expertise is needed to validate the outputs of the models. Given the pace of development of AI models, especially their increasing capabilities to handle non-structured data, this may change quicker than we think.

Challenges and opportunities for chemical industry

The opportunities and risks outlined in the previous paragraph apply to the chemical industry as well. In addition, industry is subject to strict regulation, which includes data management. Thus, although the AI applications do not necessarily need to be subject to extensive regulation, the use of data for any application, not just AI, should be. Another important insight is that innovation is not always an unalloyed good. The context in which an innovation is developed may be as important as the idea itself. Thus, industry would need policy and regulation around providing in-depth cost-benefit analyses so that the most beneficial innovations can be identified and promoted. This implies the need for an ethical framework for AI use. AI on its own is not ethical or unethical.

Counterterrorism and its impact on advancing CWC's implementation

As stated above, the OPCW is not an enforcement agency. Much of the prevention of chemical weapon and toxin use to harm groups or individuals falls with law enforcement agencies, especially in the case of non-state actors. There are many factors to consider in counterterrorism and its role in advancing the CWC's implementation. I highlight two key factors that have always been important in counterterrorism action, and that take on a new dimension with the advent of widely used AI applications. Misinformation and disinformation have always been a problem, but the sheer speed at which this can happen via social media, and the convincing appearance of AI-generated images and videos risk completely overwhelming legitimate dissemination channels. Standards and norms are critical too, as these are needed for the validation of evidence, especially in instances where AI models are used to interpret large quantities of data.

AI and the CWC

AI is a transformative and transferrable technology – the same features that enable its positive and ethical use also makes it use for malfeasance possible. Therefore, a balance is needed between exploiting the benefits of AI while safeguarding against its malicious use. This would require even more intensive and integrated international collaboration, not least to ensure that all regions of the world can share in the benefits of AI.

We know that AI can enable the discovery of compound classes not covered by the Convention. Data quality is problematic as well. For example, about 70 % of import/export data cannot be verified. AI in combination with other new technologies, such as synthetic biology or additive manufacturing can change the landscape so rapidly that responding within the boundaries of the CWC could become very difficult. Thus, are chemicals the only technologies to be monitored? And what about standards around toxins?

On the other hand, AI can provide more proactive means of implementing the CWC, for example by high-throughput analysis of satellite and drone images. Retrosynthesis tools can be used to identify unusual precursors and to track their sales for unusual activities. Large amounts of data can be analysed quickly to identify concrete risks—that is, the scope of CWC implementation can be shifted from a list-based approach to a risk-based approach. There certainly are many other possibilities and there is a good case for the OPCW joining forces with other organisations with similar concerns to reach creative solutions together.

One thing is certain: AI is here to stay and its development will only accelerate in the next years. Thus, any approach taken to integrate AI in the processes needed for the CWC's implementation must be robust, flexible and adaptable to an ever-faster changing world.

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