OVERVIEW OF EMERGING TECHNOLOGIES WITH AN IMPACT ON CHEMICAL DISARMAMENT AND NON-PROLIFERATION REGIMES

© Zmorph All-in-One 3D Printers - 3D printing is a relatively new technology that has the potential to revolutionize the way products are manufactured

ABSTRACT

The rapid advancement of emerging technologies in the chemical domain presents both opportunities and challenges for the implementation of global non-proliferation regimes, specifically United Nations Security Council resolution 1540 (UNSCR 1540) and the Chemical Weapons Convention (CWC). This article explores how dual-use technologies, which can be used for both beneficial and harmful purposes, impact efforts to prevent the proliferation of chemical weapons. While advancements have improved detection, safe handling, and destruction of toxic chemicals, they also raise significant concerns regarding their potential misuse by State and non-State actors. The article highlights the critical need for robust border, export, and end-user controls, as outlined in operative paragraph (OP) 3 (c) and (d) of UNSCR 1540, to mitigate these risks. It further discusses the implications for the CWC's verification mechanisms and offers strategic recommendations to strengthen global non-proliferation efforts in the face of evolving technological threats.

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INTRODUCTION

The emergence of new technologies in the chemical domain has significantly impacted the implementation of related disarmament and non-proliferation regimes, including UNSCR 1540 and the CWC. This article will explore the challenges and opportunities these technologies present, with a focus on their dual-use nature, the implications for border and export controls, and the potential risks they pose to global security.

On one hand, new technologies have improved the detection, safe handling, and verification of toxic chemicals. For example, advancements in modern analytical technology have allowed for the real-time detection of trace amounts of particularly acute toxic chemicals, such as chemical warfare agents.[1] Technological innovations have also helped minimize the risk of accidental exposure and reduce the environmental impact of transporting hazardous chemicals and related materials. Equally,

1 Arshid Numan et al., "Advances in Noble-Metal Nanoparticle-Based Fluorescence Detection of Organophosphorous Chemical Warfare Agents", *ACS Omega,* vol. 7, No. 31 (July 2022); Wen-Qi Meng et al., "Fluorescent probes for the detection of chemical warfare agents", *Chem. Soc. Rev.*, vol. 52, No. 2 (September 2022).

incineration and neutralization technologies have been developed to irreversibly decompose highly toxic chemical warfare agents, allowing for their effective destruction.[2] In the context of UNSCR 1540, these advancements can support the enforcement of border controls and law enforcement efforts to detect, deter, prevent, and combat illicit trafficking, in alignment with OP 3 (c).

On the other hand, these technologies can be misused for malicious activities by State or non-State actors. They may generate novel series of chemical warfare agents and new dispersion and dissemination methods. Given the dual-use potential of these technologies, OP 3 (d) of UNSCR 1540, which underscores the importance of establishing end-user and end-use controls for export, becomes of even greater significance. Thus, the impact of emerging technologies on the non-proliferation regimes has been profound.

IMPLICATIONS OF EMERGING TECHNOLOGIES ON THE NON-PROLIFERATION OF CHEMICAL WEAPONS

Emerging technologies have a wide range of ramifications for UNSCR 1540 implementation. These technologies may make it more difficult for non-State actors to create or use chemical warfare agents. Nevertheless, their potential misuse or exploitation for the development or modification of toxic chemicals also raises concerns. Autonomous molecular designs, high throughput screening, technological convergence, small-scale chemical plants, 3D printing, new dissemination and dispersion techniques, and synthetic biology, for example, have the potential to generate new categories of chemical warfare agents.

These emerging technologies are leading to the development of a new series of highly toxic chemicals and more advanced delivery systems, which may have an impact on global peace and security.[3] Given the potential for both positive and negative applications of these technologies, it is crucial to establish robust end-user and end-use controls under OP 3 (d) of UNSCR 1540. Such controls are essential to ensuring that exports of these technologies are not diverted for malicious purposes, thereby reinforcing the global non-proliferation regime.

EMERGING TECHNOLOGIES: A PARADIGM SHIFT IN CHEMICAL WARFARE

Some emerging technologies have an immense impact on non-proliferation regimes, which may influence the production of highly toxic chemicals for non-peaceful applications. Some examples of emerging technologies that may have an impact on the non-proliferation of chemical warfare agents are highlighted below.

2 Selva Balasubramanian et al., "Metal Organic Framework Functionalized Textiles as Protective Clothing for the Detection and Detoxification of Chemical Warfare Agents—A Review", *Ind. Eng. Chem. Res.*, vol. 60, No. 11 (March 2021); Sun Dal Kim and Heesoo Jung, "Neutralization and Decontamination of Chemical Warfare Agents using Homogeneous Chemical Solutions", *Ind. Eng. Chem. Res.*, vol. 62, No. 17 (2023); Wes E. Steiner et al., "Detection of a Chemical Warfare Agent Simulant in Various Aerosol Matrixes by Ion Mobility Time-of-Flight Mass Spectrometry", *Analytical Chemistry*, vol. 77, No. 15, (June 2005).

3 Rafika Nurul et al., "A New Treaty for Fully Autonomous Weapons: A Need or a Want?", *Hasanuddin Law Review*, vol. 4, No. 1 (April 2018).

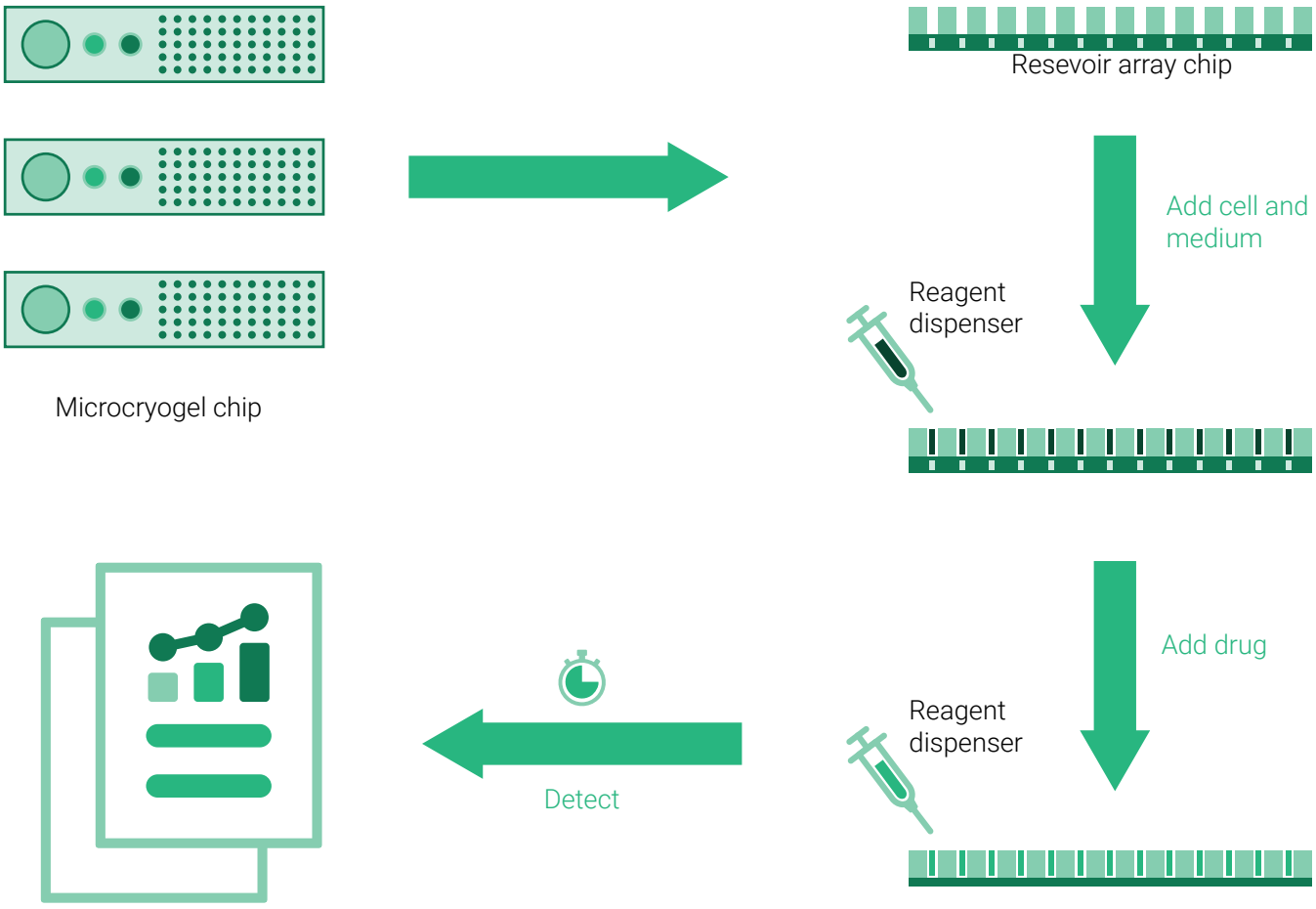

Figure 1: Schematic diagram of autonomous high throughput design screening

i. High throughput screening

High throughput screening (HTS) is a powerful technique that allows the rapid testing of thousands of chemical compounds for their biological activity.[4] This has been widely used in toxicological studies and drug discovery.[5]

It has a great impact on the chemical weapon non-proliferation regimes, both as a challenge and an opportunity. It requires careful handling and oversight to ensure its ethical and peaceful use because of its ability to screen thousands of compounds for biological activity and to determine toxicity within a short period.

ii. Autonomous molecular design

Autonomous molecular design is a rapidly growing field that uses artificial intelligence to design new molecules and materials.[6] Artificial intelligence has been increasingly adopted in recent years to expedite molecular design

4 Michael Entzeroth, "Emerging trends in high-throughput screening", *Current Opinion in Pharmacology*, vol. 3, No. 5 (October 2003).

5 Donald Wlodkowic and Marcus Jansen, "High-throughput screening paradigms in ecotoxicity testing: Emerging prospects and ongoing challenges", *Chemosphere*, vol. 307, No. 2 (November 2022).

6 Yan A. Ivanenkov et al., "Chemistry 42: An AI-Driven Platform for Molecular Design and Optimization", *Journal of Chemical Information and Modeling*, vol. 63, No. 3 (February 2023).

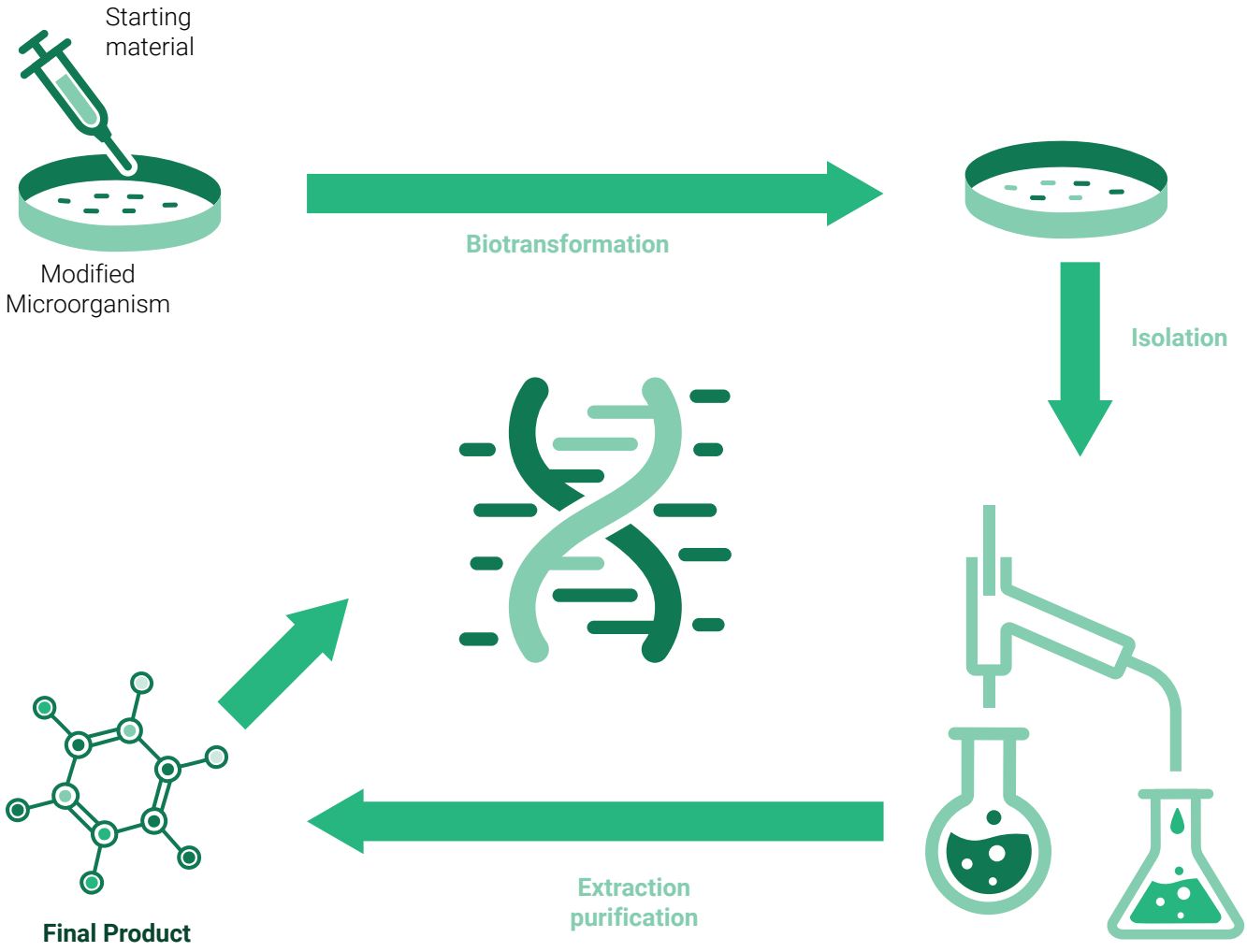

Figure 2: Schematic diagram of biological conversion of chemicals to products

in various applications. An impressive example is Chemistry42.[7] It has the potential to revolutionize the way we develop new drugs, materials, and chemicals. However, it also raises concerns about the potential misuse of these technologies for the development of chemical weapons.

iii. Technological convergence: chemistry-biology convergence

The convergence of chemistry and biology provides new and more sustainable synthetic routes to chemical production, without producing harmful side-products. Chemistry-biology convergence has an impact on the chemical weapon non-proliferation regimes as it can help to generate novel highly toxic chemicals that are not possible to make in traditional organic synthetic methods.[8]

For example, pharmaceutical-based agents (PBAs) pose a threat similar to chemical

7 Rajendra Joshi and Neeraj Kumar, "Artificial Intelligence for Autonomous Molecular Design: A Perspective", *Molecules*, vol. 26, No. 22 (November 2021).

8 Philip J. Kitson et al., "Digitization of multistep organic synthesis in reaction ware for on-demand pharmaceuticals", *Science,* vol. 359, No. 6373 (January 2018).

weapons based on their properties. There are hundreds of thousands of different PBAs that can be synthesized by conventional organic synthesis methods. The synthesis of opioid drugs is a complex process that involves several steps.

iv. Small scale chemical plants

The recent development of small-scale chemical plants that are fixed into a small space efficiently allows for the synthesis of chemicals.[9] Scientific developments in organic synthesis and changes in chemical plant design may be misused by non-State actors to make highly toxic chemicals for malicious use. They also pose new challenges to the Chemical Weapons Convention, as the regime has the authority to inspect any facility or site, but this does not apply to small plants due to their size.

v. 3D Printing

3D printing is a relatively new technology that has the potential to revolutionize the way products are manufactured.[10] In recent years, the potential threat posed by 3D printing has been widely discussed and many organizations have been working to develop strategies to address this issue. It is necessary to research the use of 3D printing for the production of chemical weapons and work with industry to develop best practices for the safe use of 3D printing technology. Equally, end-user controls for the export of 3D printing technologies, in line with OP 3(d), are essential to ensure that these capabilities are not exploited for the production of chemical weapons.

vi. New dissemination and dispersal technology

It has become increasingly evident that drones should now be considered a means of delivery for chemical weapons.[11] Advances in technology raise concerns about the potential use of commercial drones for chemical warfare as a dispersion method. These drones could deliver chemical or biological agents to the battlefield more efficiently.

FUTURE OF CHEMICAL WEAPONS NON-PROLIFERATION: CHALLENGES AND RECOMMENDATIONS

The rapid advancement of emerging technologies poses significant challenges to the effective implementation of chemical weapon non-proliferation regimes, such as UNSCR 1540 and the CWC. In the context of UNSCR 1540, the increasing accessibility of these technologies to non-State actors heightens the risk of their exploitation for the development or dissemination of chemical weapons. Equally, recent technological breakthroughs in the chemical sector present a difficult challenge to the CWC's verification regime, as they have resulted in the dispersion of technology and facilities. More technologies have emerged in the manufacturing process, and chemical contract manufacturing has formed. However, the Convention's ability to recognize such changes has not grown considerably.

9 Dominika Kunertova, "Drones have boots: Learning from Russia's war in Ukraine", *Contemporary Security Policy,* vol. 44, No. 4 (October 2023).

10 Douglas B. Walters et al., "Safety, security and dual-use chemicals", *Journal of Chemical Health and Safety*, vol. 22, No. 5, (September–October 2015).

11 Dominika Kunertova, "Drones have boots: Learning from Russia's war in Ukraine", *Contemporary Security Policy,* vol. 44, No. 4 (October 2023).

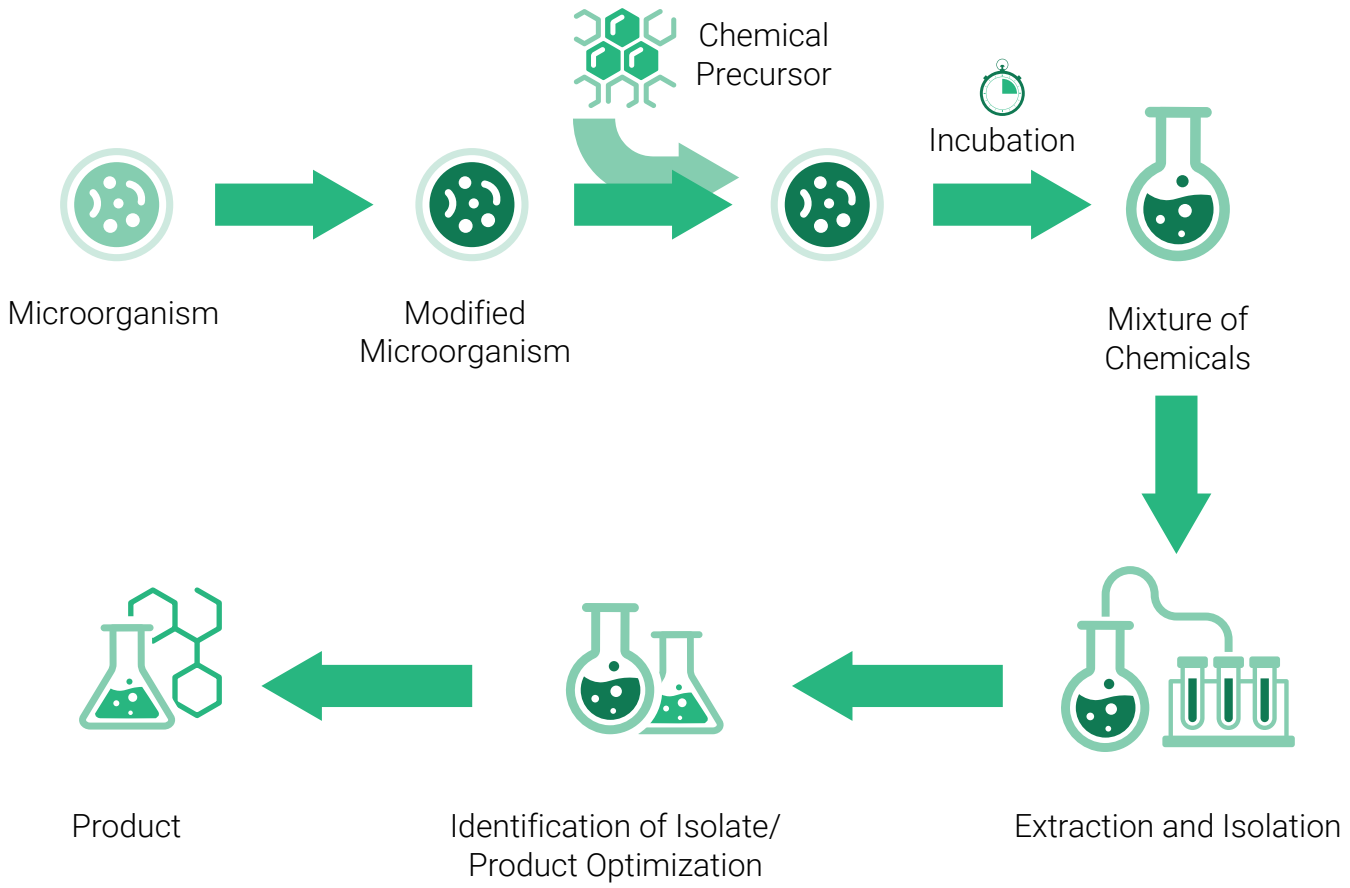

Figure 3: Schematic diagram of opioid synthesis through genetically modified microorganisms

There are many suggestions for non-proliferation regimes to prevent the re-emergence of chemical warfare agents in the wake of advanced technologies. However, this article is focused on five key technological aspects namely high throughput screening, autonomous molecular design, chem-bio convergence, small-scale chemical plants, and the use of drones. Five strategies have been identified for mitigating the risks posed by these key emerging technologies, which are:

- Assessing the impact of new technologies on chemical weapon control
- Awareness of emerging technologies
- Standardized policies and procedures
- Capacity building
- Integrated approach for promoting best practices for domestic stakeholders

Given the dual-use nature of these technologies, establishing end-user and end-use controls for exports is crucial to ensure they are not diverted for malicious purposes. This is in direct alignment with the requirements of OP 3 (d).

Artificial intelligence's recent rapid technological growth and the concerns it raises highlight the critical need for robust export controls, as outlined in OP 3 (d). Policymakers and regulators must ensure that these controls are comprehensive

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and globally coordinated to effectively mitigate the risks and capitalize on the benefits of AI and other emerging technologies.

One of the most important strategies to prevent the misuse of technologies, in line with UNSCR 1540's OP 3 (c) and (d), is to enhance the capacity of stakeholders in the supply chain and to increase the number of supply chain security vulnerability assessments. These measures are essential for detecting, deterring, and preventing illicit trafficking and controlling the export and trans-shipment of potentially dangerous materials.

Many disarmament and non-proliferation regimes have repeatedly debated the implication of emerging technologies in the chemical, biological, and nuclear domains. In order to address this threat, Member States should enhance their cooperation and collaboration to prevent possible misuse of emerging technologies for malicious purposes. International regimes working on the non-proliferation of weapons of mass destruction must establish capacity-building programmes for chemical, biological, radiological and nuclear security management to promote best practices in security by providing tools and knowledge to mitigate the risks posed by both chemical accidents and the potential misuse of toxic chemicals, including the threat of chemical terrorism.

Collaborating with all domestic stakeholders, as well as regional specialists and international organizations, to develop a strategic policy to prevent malicious State actors and non-State actors from gaining access to new technologies would likely bring a beneficial outcome to the concern. Such collaboration is essential for fulfilling the international obligations under OP 3(c) and (d) of UNSCR 1540 and the CWC, and it is crucial for their effective implementation.