KnE Social Sciences
ICHSSE
International Conference Health, Social Science & Engineering
Volume 2023

Conference Paper

Technological Advances and Evolution of Biowarfare: A Threat to Public Health and Security

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Abstract.

Research in public health and medical sciences has always placed a high priority in managing disease outbreaks, effective treatment capacities, and overall human health and wellbeing. Despite the fact that advances in biology, biotechnology, and medical research have proven to have sufficient value in terms of lifesaving treatments, these have also presented major challenges in their effective utilization. Hence, potentially posing serious risks in the form of bioweapons, thereby, endangering governance frameworks that prioritize biosecurity and counter-biological warfare. In this review paper, a thorough literature review has been conducted to explore the critical aspects between advances in biology and their potential misuse, which could result in serious risks to public health and security. The history of biowarfare has been studied, and the results identify major criteria that have been used in deeming a biological agent fit for the use in mass destruction programs. Five historical biological warfare agents (*Bacillus anthracis, smallpox, Yersinia pestis, Vibrio cholerae, and Francisella tularensis*) have been studied critically to conclude that not all biological agents may act as bioweapons, but only those agents meeting these criteria may cause catastrophic damage. This paper examines key risks associated with bioweaponry posed by the convergence of biotechnology and artificial intelligence as evident in today's world of innovation. Based on the situational analysis of the COVID-19 pandemic, the author also discusses some of the major shortcomings of the international framework and the healthcare system in handling future biological attacks having the potential of mass destruction. Through this paper, associations between different stakeholders, scientific communities, and research groups are highly recommended along with identifying the problem at its roots.

Keywords: bioweapons, biological toxin, biotechnology, artificial intelligence

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Published 4 August 2023

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICHSSE Conference Committee.

1. Introduction

Biological science and technology have played a crucial role in human progress and prosperity throughout the course of history [1,2]. Additionally, they play an important role in implementing the 2030 Agenda for Sustainable Development[2,3]. On the one hand, major advances could be observed in the field of epidemiology, public health, and the control of infectious diseases, while on the other hand, in a world that is rapidly developing in terms of the biological sciences, advances in biosecurity and further preventing the proliferation of biological weapons have continued to pose serious challenges [1,4,5]. Biotechnology, for example, has made the process of manipulating organisms' genetic makeup easier, cheaper, and faster [1]. Advances like Clustered Regularly Interspaced Short Palindromic Repeats (CRISPER) technology have proven helpful in developing medicines for otherwise incurable diseases such as cancer, muscular dystrophy, huntingtin's disease, and blood disorders [6,7]. Yet, many of these developments relate with or are improved by other technologies, including the emerging ones that pose a risk to be misused leading to the proliferation of biological weapons[1]. In particular, three emerging technologies namely artificial intelligence (AI), additive manufacturing (AM) or 3D printing, and robotics [8] on one hand aim at making efficient treatment and drug development, on the other hand, major challenges exist when these technologies are used together with an intent to cause mass destruction and challenge human life through biological agents. Additionally, they could give rise to new possibilities for biological weaponry and increase cyber attack potential over digitalized biological records [8].

The World Health Organization defines biological weapons as microorganisms designed to kill or harm humans [9]. It is a microorganism - such as a virus, bacteria, fungus, or another toxin - developed and released intentionally to cause illness and death in animals, humans, and other organisms. In public health, biological agents like the plague, botulinum toxin, or anthrax can cause large deaths in a short period of time and are difficult to contain as evidenced by the past biowarfare programs and threats posed in front of the international community[10,11].

Many ancient societies used poisoned wells or arrowheads armed with poisons for warfare. In mid-16th century Europe, outbreaks of the plague were exacerbated by Mongol invasions that threw plague victims into besieged cities, while British settlers infected Native Americans with smallpox by giving them blankets [12]. Thus, according to some scholars, biological warfare has a rich history similar to that of warfare [12]. Such key instances of biowarfare are outlined in Figure 1 below:

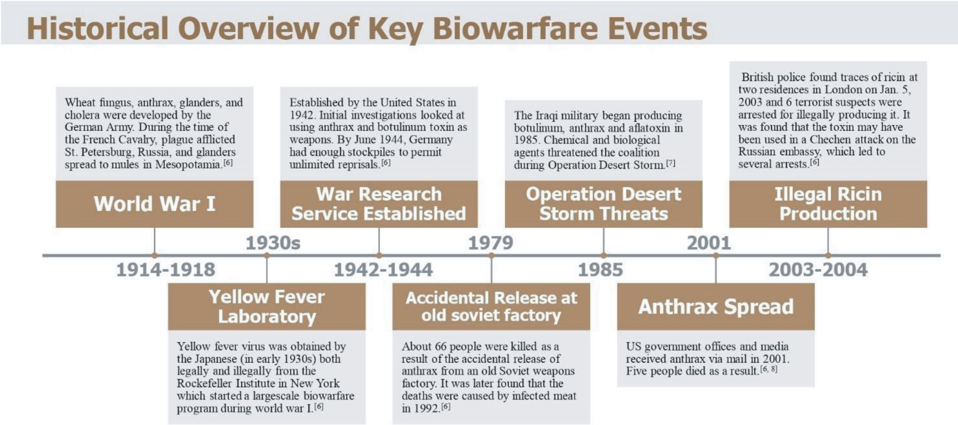

Figure 1: A Historical Overview of key biowarfare events. *Presented is a timeline that shows key events that occurred as a result of bioweapons. It has been shown that misuse of biological agents has been linked to lethal outcomes since World War I until the early 21st century[13-15]. With modern advancements in technology, these threats and challenges have multiplied and pose the threat of a targeted bio attack that can affect a broader community.*

From this historical evidence, it has become clear that bioweapons are unconventional weapons, that, as compared to more sophisticated technology such as missiles, are not only capable of doing great harm but can also be produced at a reasonably low cost. Moreover, their effects spread slowly, so detonating them gives the perpetrator plenty of time to escape undetected.

Though accidentally leaked and not intended to cause mass destruction, SARS-CoV-2 proved to be life-threatening to millions of people worldwide. Even the world's finest healthcare systems were challenged by COVID-19, a pandemic that raised questions about a nation's preparedness for any future bio attacks this large. Therefore, it is imperative to determine the key characteristics of a biological agent that can be misused to cause mass destruction and to figure out the major loopholes in existing laws and norms aimed at preventing bioweapon attacks[16]. As evidenced by historical bioweapon attacks, the haphazard situation caused by the COVID-19 pandemic, and the ongoing scientific advancements that have proven to be both beneficial and detrimental to the developing world, the present situation is critical and must be adequately addressed.

In order to critically study the existing scenario and draw conclusions on major challenges posed by the perceptual misuse of biological agents, the section below is divided into different aspects ranging from analyzing the type of biological agents used in bioweapons, risks due to the development of databases, biotechnological advancements and its convergence of with artificial intelligence. It further discusses the challenges with respect to the current scenario and the effectiveness of The Biological and Toxin Weapons Convention (BTWC) to prevent the development and misuse of Bioweapons.

This study thus aims to direct the policymakers, scientific community, and different stakeholders to take necessary actions in order to strengthen the existing systems, increase surveillance, and put significant emphasis on bioethical education for young scientists.

2. Method

This study was conducted by a thorough literature review by performing a primary search with keywords such as 'bioweapons', 'bio warfare', 'artificial intelligence, 'biotechnology', and 'regulations' using search engines, namely, PubMed, Google Scholar, Research gate, Elsevier. In addition, various websites and books containing articles, reports, and abstracts on google were reviewed. About 35 different articles have been studied and cited in this paper.

The common agents of choice for biological warfare programs were studied to find out the key features that make a biological agent an ideal candidate to be used as a bioweapon. Out of numerous microorganisms that are researched today, there are a few microbes (like *Bacillus anthracis, smallpox, Yersinia pestis, Vibrio cholerae, and Francisella tularensis*) that have been reported to hold potential risks as bioweapons. These five microbes were in-depth studied and their key features are as follows:

2.1. Anthrax (Bacillus anthracis)

It has been seen that Anthrax (*Bacillus anthracis)* spores are the first choice in most of the past biowarfare programs [13]. If large numbers of anthrax spores are breathed in, they can lead to inhalation of anthrax, a fatal disease unless treated promptly with penicillin-type antibiotics immediately [17]. If kept dry and away from direct sunlight, these spores can survive for more than 100 years. As a result of their long shelf life, they are ideal for weaponization in an aerosol delivery device. Until they fall to the ground, dispersed spores remain infectious. However, sunlight usually kills them.

2.2. Smallpox

In contrast to anthrax, smallpox is contagious, making it a potential bioterrorism agent. Since smallpox was eradicated through widespread vaccinations in 1977, natural threats are no longer present [17]. Nevertheless, if the smallpox virus gets into the wrong hands (which is preserved in the US and Russian laboratories), it has the power to spread rapidly and easily between people [17].

2.3. Plague (Yersinia pestis)

Bacterium *Yersinia pestis* causes plague [18]. *Y. pestis* has the capability to infect a number of hosts [18,19]. Primary pneumonic plague can be transmitted via aerosols or food, but most arise from flea bites. During feeding, an infected flea will regurgitate bacteria into the bite site and thus infect the host [18]. This niche's gene expression is influenced by temperature, which allows it to survive in two distinct environments [18].

Humans who become infected with bubonic plague are easily treated with antibiotics, but if the infection spreads to the lungs, it can turn into pneumonic plague, which is difficult to treat with antibiotics [17].

2.4. Cholera (Vibrio cholerae)

Cholera poses a bioterrorism risk because it is a severe and at times life-threatening gastrointestinal disease [17]. Due to its difficulty in spreading between people, it is deliberately added to main water bodies in large amounts for effectiveness.

US, South Africa, Iraq, and Japan, have historically weaponized *Vibrio cholerae* [17]. In the case of Japan, for example, during World War II, *Vibrio cholerae* was one of the main organisms of interest in warfare. The Japanese program between 1932 and 1945 is believed to have led to the deaths of about 10,000 inmates through experimental infection[20]. Many of the prisoners died from anthrax, gas gangrene, cholera, plague, dysentery, and meningococcal infections brought about by inoculation with these agents [20].

2.5. Tularemia (Francisella tularensis)

As few as ten Francisella tularensis organisms must be inoculated or inhaled to cause the disease, which makes it one of the most infectious bacteria known [21]. There are several features that make it an extremely dangerous potential biological weapon, including its ability to spread easily and cause substantial illness and death (Figure 2) [21].

A hardy virus first developed by the Japanese in World War II and subsequently stored by the United States, *F. tularensis* can persist in the hay, decaying animal carcasses, and wet soil for weeks regardless of the temperature [17]. The Working Group on Civilian Biodefense considers that an aerosol release is the most dangerous way to use *F. tularensis* in a weapon because it would cause the greatest amount of medical and public health complications [21].

The World Health Organization (WHO) reported in 1970 that about 50 kg of virulent F tularensis spores in a city with 5 million people could affect approximately 250,000 people with incapacitating injuries, including 19,000 deaths [21]. A clear indication from these statistics is how potentially dangerous this bacteria is if misused.

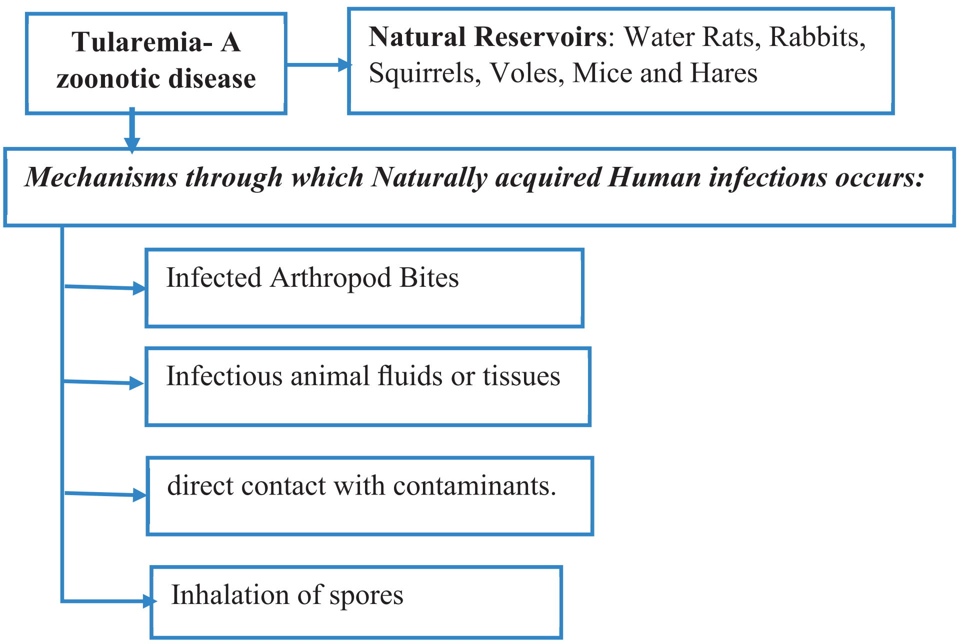

Figure 2: The pathogenicity of *Francisella tularensis* causing Tularemia. *The given figure indicates the natural reservoirs where Francisella tularensis could be found along with mechanisms through which it can infect humans to cause Tularemia.*

3. Results

The major findings after studying these five microbes used as bioweapons indicate that these microbes share certain traits that make them ideal candidates to be used as a bioweapon. Below is a diagram (Figure 3) illustrating these key characteristics of an ideal bioweapon which makes them appealing to misuse. Thus, any other microorganism with such characteristics has the potential to be used as a bioweapon. Hence, A rigid global policy rejecting such weapons and their development is the first step towards prevention, and secondly, the development of an effective infrastructure to ensure the identification of such microorganisms and formulation of effective policies to limit their usage in industries is required [20].

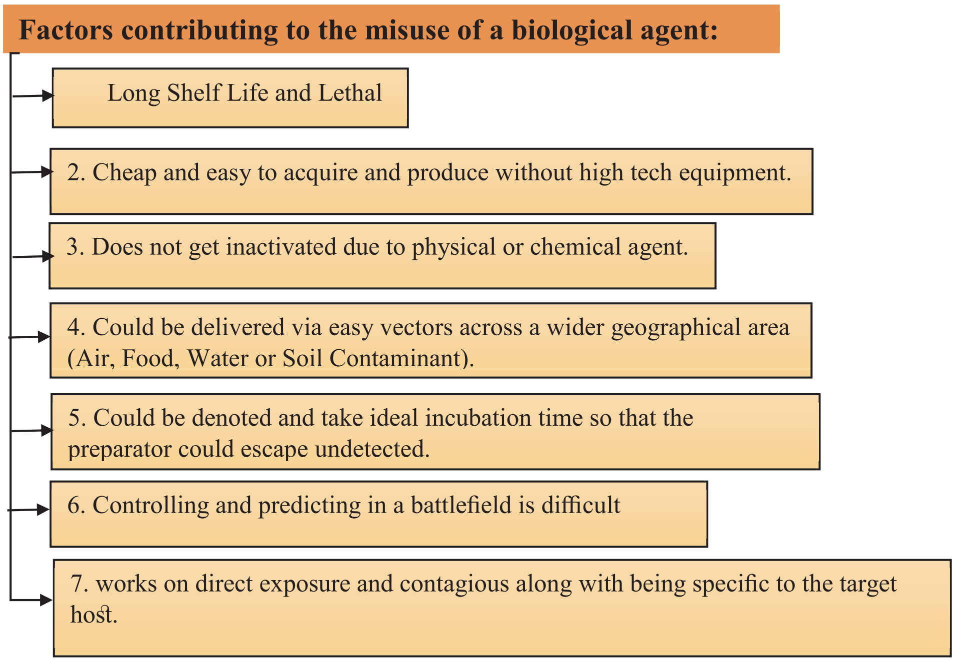

Figure 3: Main criteria responsible for the misuse of biological agent. *The figure illustrates seven defining characteristics of a biological agent that make it suitable for use as a bioweapon. Any biological agent that possesses these characteristics could be dangerous if misused. One of the most significant is its easy accessibility to predatory laboratories and private research centers seeking to develop lethal bioweapons.*

The study also found that the synergy between artificial intelligence and biotechnology presents significant opportunities for a perpetrator to misuse it and cause a global biothreat if the existing policies and surveillance systems are not adequately strengthened.

It is seen that the logic of artificial intelligence is not discrete like a fighter jet or locomotive, but rather the logic of electricity, computers, or the internal combustion

DOI 10.18502/kss.v8i14.13853

engine. This makes it a valuable tool that could contribute to economic growth and disruption on a scale comparable to another industrial revolution. In general, AI applications across society are likely to be highly beneficial, but both harmful and responsible actors will make use of AI in security applications [1]. Currently, artificial intelligence (AI) and biotechnology are undergoing rapid development, and in combination, both could help make innovations in medical precision, biosurveillance, medical countermeasures, and public health emergency response [22]. As far as the military is concerned, it provides humans with a lot of scopes, such as enabling them with abilities that are above the typical range or level of functionality of humans [1]. Using machine learning and genomic prediction to analyze DNA could enable the identification of more viable candidates for human enhancement procedures, including gene editing. Data on military health and genomics can also be used to determine the type of health treatment soldiers need for specific missions (vaccines, antibiotics, etc.) a soldier's resistance to a specific pathogen, for example, could be enhanced by the treatment [1, 2]. AI and machine learning can be used to create models that predict the effect a new enhancement will have on the soldier's genes and health [1].

However, despite the advantages of current AI systems, there are several major limitations that make them a major threat, such as their limited intelligence and vulnerability with respect to autonomy and understanding (Figure 4). Using artificial intelligence for biological and medical analysis could lead to ultra-targeted biological warfare. In past biological weapons programs, victims were targeted simply by their geographic location. In the future, advances in biotechnology may allow foreign actors to use biological agents over large geographical areas, but only target specific individuals [1,23]. These key threats are highlighted in Figure 4, below. It is further indicated that along with the existing challenges that AI systems face today, the problem could be exuberated to become more disastrous. Hence, in addition to balancing the advancements in scientific research, attention must also be paid to the fact that such policies do not topple a nation's ability to scientifically develop and thrive and utilize such technology for lifesaving treatments.

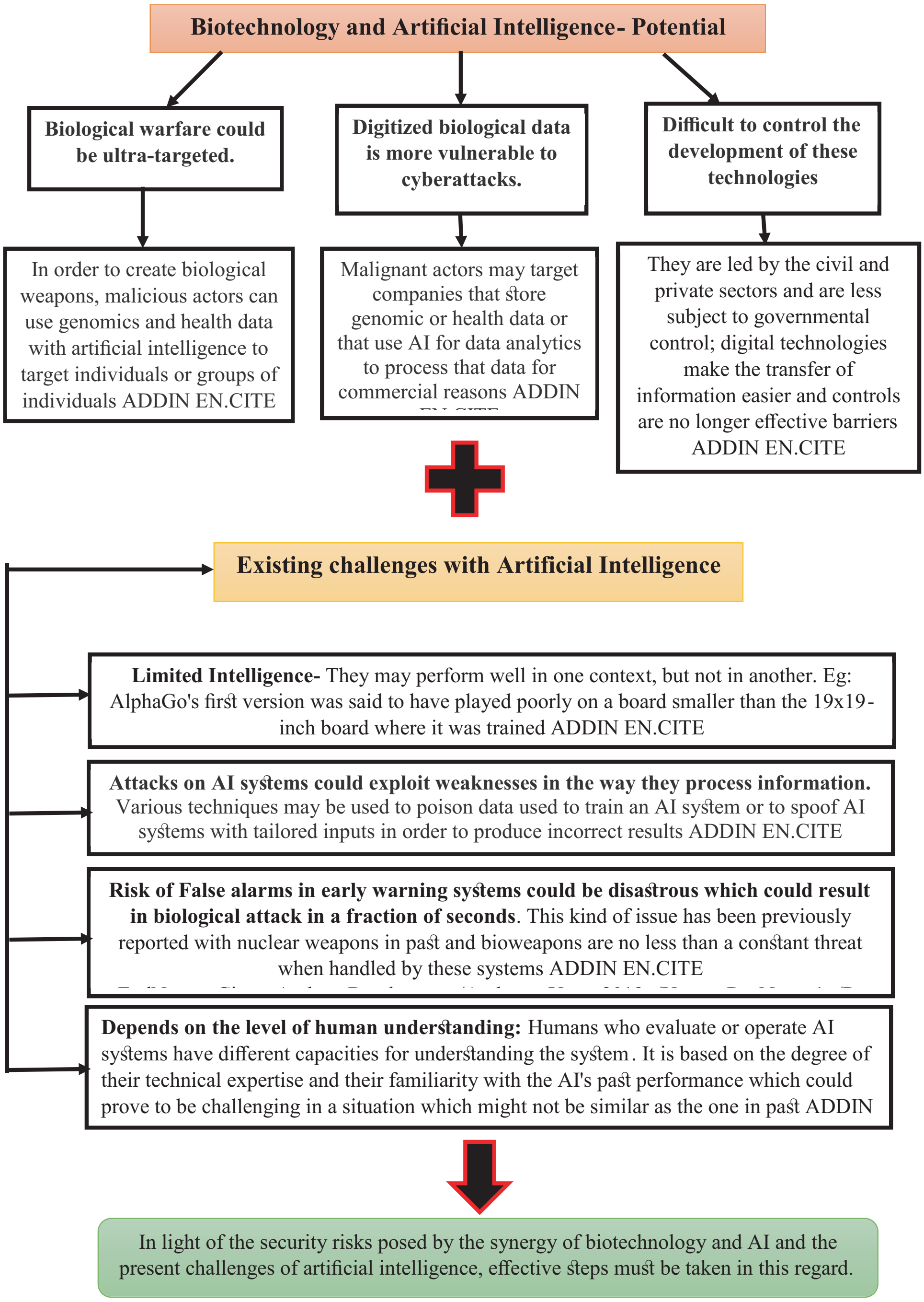

Figure 4: Threats due to the synergy of biotechnology and artificial intelligence coupled with existing challenges in AI systems. *This figure gives an overall picture of major security problems that could occur if both biology and AI are used simultaneously in bioweaponry. These challenges could lead to an ultra-biowarfare, vulnerability of digitalized gene data, and difficulty in controlling these technologies. All these combined together, make a deadly combination of risks that the Policymaking and scientific community face today, and these aspects must be addressed at the earliest with specific solutions.*

4. Discussion

After identifying major threats associated with bioweapons, it is imperative to highlight significant challenges associated with technological advancements. Through the situational analysis of the COVID-19 pandemic, it becomes a necessity to ponder upon existing regulations and their effectiveness in the present scenario. Different countries have different regulations regarding biomedical and genetic research[22-26], but a weapon based on such research is mostly prohibited under the 1975 Biological Weapons Convention. Recent advances, however, have some experts concerned that it may make it easier to develop more powerful and lethal pathogens in the future [27].

Since the sequence of the human genome was first published in 2003, it has been easier and more affordable since then with the advancements in computing technologies to investigate the DNA of individuals, pathogens, and plants [27]. At present, almost a half-million different organisms have been sequenced, and some of this information is easily accessible on the Internet, such as in the Kyoto Encyclopaedia of Genes and Genomes [28]. Consequently, Gene maps of dangerous microbes, such as bacteria, fungi, and viruses, are widely available publicly and are quite vulnerable to misuse [28,29]. It is possible for scientists bent on destruction to try to clone bacteria and viruses with extremely high levels of virulence using technology [29]. In addition, it should not be forgotten that there are many underpaid microbiologists who are more than willing to work for undisclosed clients who create incurable ”designer diseases” [29]. This suggests that even without an intentional attack, there is a serious threat of a pandemic [27].

The COVID-19 Pandemic, which killed millions, was the subject of numerous conspiracy theories claiming that the virus could have been a leaked bioweapon. Nevertheless, a study published in Nature Medicine clarified that it was a product of natural evolution, as a result of the analysis of the genome sequences available [30,31]. Whether intentionally leaked or naturally evolved, the quantum and magnitude of the devastation caused by the SARS-CoV-2 virus and its mutations could be felt by every nation. It has claimed thousands of lives and economies have been disrupted, creating an uncertain future for millions. This Pandemic unfurled critical flaws in the existing preparedness plans and the detection of an outbreak is still a major challenge. The adverse impacts of COVID-19 are more evident to the poorest of the poor when it comes to food production, transportation, processing, and distribution [32]. As of 2018, 820 million people were food insecure; by 2019, 135 million people were living with chronic hunger. This number nearly doubled to 265 million by 2020 under COVID-19 [32]. Moreover, despite the availability or potential availability of a vaccine in an emergency situation, a large supply of vaccines is still a key challenge [32]. These examples clearly indicate that any lethal mutation of such virus could potentially be considered in biowarfare with the aim of jeopardizing the entire nation or a population as a whole.

With a view to maintaining a system of checks and balances with respect to scientific research and bioweaponry, and to prohibit the development of such weapons, the Biological Toxin Weapon Convention (BTWC) was formulated in 1972 and became effective in 1975. As regards biological agents and toxins, it was the first intergovernmental treaty that prohibited their exploitation, production, stockpiling, and transfer for any purpose other than those of protection or peaceful purposes. It also prohibits the design, development, or manufacture of weapons, equipment, or means for delivering such agents [33]. For states to comply with this convention, bilateral or multilateral cooperation is required [33].

However major loopholes exist in this treaty which challenges its working in the current scenario [34]. First, the undersized implementation support unit makes it difficult to accomplish much more than coordinating meetings and conferences with only three employees [35]. If a biological attack were to take place, this support staff is unlikely to play a role. Thus, the BTWC needs to be supported by a dedicated expert forum to discuss the implications of scientific advances on treaties and to review advances in science and technology on a more systematic and regular basis [35].

Secondly, the current Convention may not adequately address all risks associated with the changes in life sciences and beyond [34]. As a result of advances in synthetic biology, agents based on DNA or RNA but with entirely synthetic bases have developed which may not necessarily cause general harm to humans. The agents may instead target particular biological processes, such as the human nervous system or immune system [1]. The BTWC does not explicitly cover these synthetic constructs. The balance that determines military compliance with the BTWC could shift if militaries find novel biological agents and related technology attractive [1]. In addition to their obvious benefits, advancements in synthetic biology and gene editing techniques like CRISPR have raised serious ethical, biosafety, and biosecurity concerns [1,7]. As identified, the novel gene editing techniques, like CRISPR, pose distinct challenges in terms of international security and arms control (Figure 5).

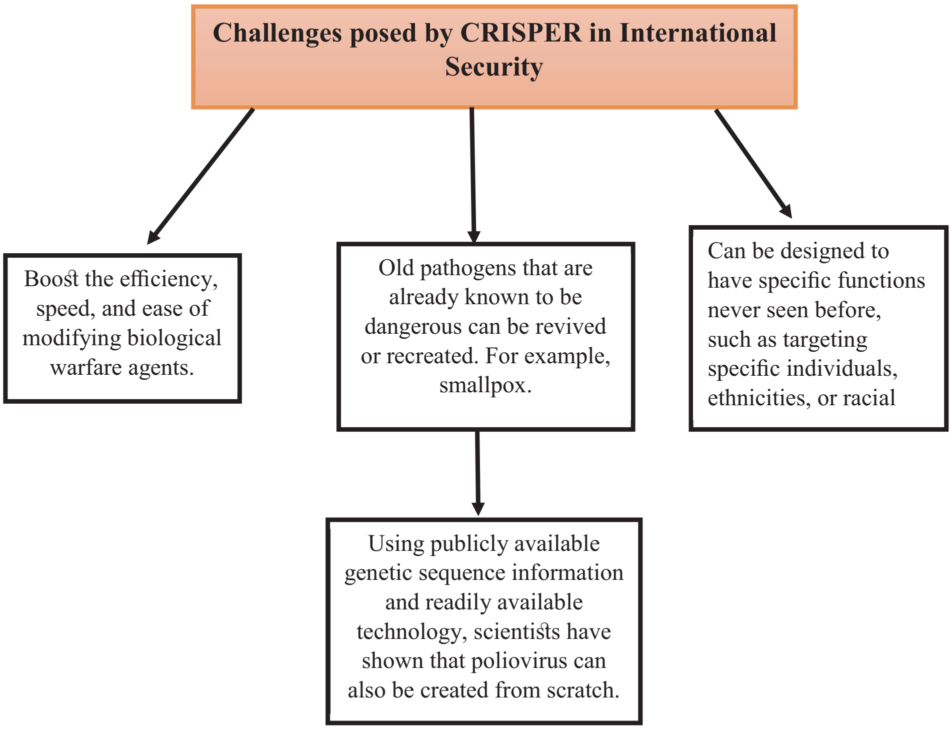

Figure 5: Challenges Posed by CRISPER in International Security. *The given figure highlights three key reasons which can be threats to biosecurity if not adequately addressed by international conventions and policies. This gives an overview of the importance of simultaneously evolving the existing law and policies with technological and scientific advancements.*

There are multifaceted threats that are posed by bioweapons and the existing policies and preparedness plans, as evident from the COVID-19 pandemic, have not proven to be effective in a biothreat. Hence there is a need for a stringent policy and review framework that could work well in tandem with the individual country policies effectively. Considering the vast biosecurity threats resulting from their convergences, thorough risk assessments are crucial[16, 22]. To assess the risks associated with emerging technologies, including artificial intelligence and biotechnology, the Association for the Advancement of Science (AAAS), the Federal Bureau of Investigation (FBI), and UNICRI (United Nations Interregional Crime and Justice Research Institute) should form an interprofessional working group composed of experts[22]. At the same time, the association between the scientists involved in human health and animal studies should be strengthened so that the early risk assessment could be strengthened and any biological agent with epidemic or pandemic potential could be detected and further researched. The key consideration should also be given to the behavioral and psychological aspects of the general population at risk of a bioweapon attack and emergency systems must be strengthened.

Hence, the implementation and evaluation of a global and agile biosecurity framework that covers the entire spectrum of public-health interventions - from scientific research and early warning to policy formulation, implementation, and evaluation at the same time emphasizing ethical education from early educational levels are highly recommended. The World Health Assembly (WHA) research bodies, UNIDIR (United Nations Institute for Disarmament Research), and UNITAR (United Nations Institute for Training and Research) should evolve further to help support national preparedness for biological warfare. The role of science, technology, and innovation is vital.

5. Conclusion

In conclusion, the paper finds that despite advances in technology that potentially facilitate the creation and use of bioweapons, both international and governance frameworks are inadequate to address these issues, and directional efforts are necessary. Not every biological agent holds a disastrous potential, but those which do, need to be adequately studied and policy formulated so that they are not misused. So, on one hand, when it has become increasingly critical to prevent the misuse of biological agents, on the other hand, any efforts to regulate new weapon technologies or the application of new technologies to weapons should not hinder a country's technological growth and innovation.

Acknowledgment

I am extremely thankful to my institution Bhaskaracharya College of Applied Sciences, University of Delhi for the constant guidance, support, and encouragement in this paper. I am also thankful to all the reviewers who gave their valuable inputs to the manuscript and helped in completing the paper.

Conflict of Interest

The author declares no conflict of interest.

References

[1] Brockmann K, Bauer DS, Boulanin DV. Bio Plus X: Arms control and the convergence of biology and emerging technologies. SIPRI Publications; 2019.

[2] Verma N. ”How to technology changes human life,” in Times of India, ed., 2021.

[3] Chen S, Guo L, Wang Z, Mao W, Ge Y, Ying X, et al. Current situation and progress toward the 2030 health-related Sustainable Development Goals in China: A systematic analysis. PLoS Med. 2019 Nov;16(11):e1002975.

[4] Beck V. ”Advances in life sciences and bioterrorism. Risks, perspectives and responsibilities,” (in eng), EMBO Rep. 2003 Jun;4(Suppl 1):S53-S56. https://doi.org/10.1038/sj.embor.embor853

[5] Foley M. “Genetically engineered bioweapons: A new breed of weapons for modern warfare.” Dartmouth Undergrad Journal of Science, vol. Appl Sci (Basel). 2013.

[6] Fernández CR. ”Eight diseases CRISPR technology could cure.” Accessed.

[7] Naik S. ”Biological weapons: The impact of new technologies,” CBW Magazine, vol. 12, no. 2, Cover Story, 2019.

[8] Bensch F. ”How emerging technologies increase the threat from biological weapons.” Accessed.

[9] News WI, editor. WION. 2020.

[10] W. H. Organization, ”Biological weapons- Overview.”

[11] Goel AK. Anthrax: A disease of biowarfare and public health importance. World J Clin Cases. 2015 Jan;3(1):20–33.

[12] van Aken J, Hammond E. ”Genetic engineering and biological weapons. New technologies, desires and threats from biological research,” (in eng), EMBO Rep. 2003 Jun;4(Suppl 1):S57-S60. https://doi.org/10.1038/sj.embor.embor860

[13] Hooker E. ”Biological Warfare.”

[14] Zilinskas RA. Iraq’s biological weapons. The past as future? JAMA. 1997 Aug;278(5):418–424.

[15] NPR. ”The anthrax investigation,” in ”Special Series,” 2011.

[16] Charlet K. ”The new killer pathogens: Countering the coming bioweapons threat.”

[17] Newman T. Bioterrorism: Should we be worried? Medical News Today; 2018.

[18] Senior NJ, Sasidharan K, Saint RJ, Scott AE, Sarkar-Tyson M, Ireland PM, et al. An integrated computational-experimental approach reveals Yersinia pestis genes

essential across a narrow or a broad range of environmental conditions. BMC Microbiol. 2017 Jul;17(1):163.

[19] Perry RD, Fetherston JD. Yersinia pestis—etiologic agent of plague. Clin Microbiol Rev. 1997 Jan;10(1):35–66.

[20] Riedel S. Biological warfare and bioterrorism: a historical review. Proc Bayl Univ Med Cent. 2004 Oct;17(4):400–406.

[21] J. H. C. f. P. H. Preparedness.

[22] O'Brien JT, Nelson C. Assessing the risks posed by the convergence of artificial intelligence and biotechnology. Health Secur. 2020;18(3):219–227.

[23] Aryan J. "A look at China's biowarfare ambitions," Expert Speak.

[24] Ryan JR. Legal aspects of biosecurity. Biosecur Bioterror. 2016;243–261.

[25] Gronvall GK. Prevention of the development or use of biological weapons. Health Secur. 2017;15(1):36–37.

[26] Naik S, Ramanathan A, Naik S, Ramanathan A. The new bioweapons peril a case to revisit the biological weapons convention. Indian Public Policy Review. 2022;3(1):59–76.

[27] Apps P. "Commentary: The next super weapon could be biological," Commentry.

[28] Alisha Anand PA; Security and Technology Programme, UNIDIR. Life Sciences, International Security and Disarmament Conference Report. 2020 innovations Dialogue. United Nations Institute of Disarmament Research; 2020.

[29] Shwartz M. "Biological warfare: An emerging threat in the 21st century," ed.: Standford News Service, 2001.

[30] O. f. w. a. feed, "Is coronavirus a leaked biological weapon? Scientists don't think so," in Mint, ed, 2020.

[31] Andersen KG, Rambaut A, Lipkin WI, Holmes EC, Garry RF. "The proximal origin of SARS-CoV-2." Nat Med. 2020 April 01;26(4):450-452. https://doi.org/10.1038/s41591-020-0820-9

[32] Lambert H, Gupte J, Fletcher H, Hammond L, Lowe N, Pelling M, et al. COVID-19 as a global challenge: Towards an inclusive and sustainable future. Lancet Planet Health. 2020 Aug;4(8):e312–e314.

[33] "Biological Weapons Convention (BTWC) Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons (BTWC)," Biological Multilateral.

[34] Samore G. ”Bioweapons research is banned by an international treaty – but nobody is checking for violations,” International Affairs, Research.

[35] Gerstein D. Could the bioweapons treaty be another tool for addressing pandemics? Bull At Sci. 2021.