„Ante Portas – Security Studies”
2023, No 20
DOI: 10.33674/1202412

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NATIONAL SECURITY IN THE CONTEXT OF THE DEVELOPMENT OF GENETICALLY ENGINEERED BIOWEAPONS

Abstract: *In recent years, the emergence of biosecurity as a key concern on the national security agenda can be attributed to two main objectives. These trends include advancements in science and technology, the appearance of novel diseases, the process of globalization, and the altering nature of conflicts. The potential use of genetic advancements to create ethnic bioweapons poses a significant risk to national security. These weapons could target particular ethnic or racial groups based on their genetic markers. The increased risks and challenges for national security are heightened when one considers how difficult it can be for governments and law enforcement agencies to monitor the potential use of these technologies. Considering the current technological progress in the field of biological sciences, the aim of this paper is to demonstrate the potential and importance of genetically engineered bioweapons in the context of national security issues and threats related to weaponization of genome editing biotechnologies.*

Keywords: *national security, medical challenges, biological weapons, biowarfare, genome editing, medical intelligence, weaponization of biotechnology.*

Introduction

Microbes that infect and grow in a host, causing a lethal or debilitating disease, are known as Biological Weapons. These organisms can either be naturally occurring or genetically modified strains. Biological Weapons encompass any toxin or organism found in nature, such as viruses, bacteria, or fungi, that can be utilized to harm or kill individuals. Toxins are harmful

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substances created by living organisms. They can be used to target living organisms such as humans, animals or they can be used to contaminate non-living substances such as air, water, and soil[2].

Since 1925, the Geneva protocol has prohibited the use of biological and chemical weapons in warfare. The WHO recognized the danger of these weapons during the Vietnam War and Cold War, after UN resolution 2162B (XXI) was passed in 1967, which denounced any actions that violated the Geneva protocol. Consequently, the WHO published a report in 1970 called Health Aspects of Chemical and Biological Weapons, which was later revised in 2004[3]. The use of toxins generated by living organisms falls under the provisions of both the Biological Weapons Convention and the Chemical Weapons Convention, resulting in an overlap between biological warfare and chemical warfare.

Biological weapons have been used throughout history. From the use of smallpox-infected blankets by European colonizers against Native Americans[4], to the anthrax attacks in the United States after 9/11[5]. From ancient times when plague-ridden corpses were catapulted over city walls, to the current day concerns about bioterrorism, these weapons have proven to be a terrifying and deadly force. In 1346, during a Tatar attack on the seaport town of Caffa which was under Genoese control, the use of plague as a weapon was first reported. The Tatars, who were weakened by the plague, hurled plague-infected victims into the town, resulting in an epidemic that spread among the Genoese forces[6].

Many issues raised at the scientific and research level find imitators in recent popular culture. A contemporary reflection of the problematics of modern bioweapons has been shown in the James Bond film ”No Time To Die”. The movie shows the possibility of use of a bioweapon called Project Heracles. The weapon can be customized to an individuals’ genetic composition using nanomachines. In fact, there is currently a dynamic trend in the development of nanomedicine in the real world. An example of such research is the emerging technique of nanogene delivery which holds promise in addressing various biological and medical challenges. Its key aspect involves

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[2] E. Onyenekenwa, *Biological Weapons-Agents for Life and Environmental Destruction*, "Research Journal of Environmental Toxicology" 2012, No 6, pp. 65–87.

[3] H. J. Jansen, F. J. Breeveld, C. Stijnis, M. P. Grobusch, *Biological Warfare, Bioterrorism, and Biocrime*, "Clinical Microbiology and Infection" 2014, Vol. 20, No 6, pp. 488-496.

[4] K. B. Patterson, Runge T., *Smallpox and the Native American*, "The American Journal of the Medical Sciences" 2002, Vol. 323, No 4, pp. 216-22.

[5] Bush L. M., Perez M. T., *The Anthrax Attacks 10 Years Later*, "Annals of Internal Medicine" 2012, Vol. 156, No 1, p. 41.

[6] K. A. Glatter, P. Finkelman, *History of the Plague: An Ancient Pandemic for the Age of COVID-19*, "The American Journal of Medicine" 2021, Vol. 134, No 2, pp. 176-181.

delivering genetic material into cells, which must eventually reach the nucleus for the desired function to be realized[7].

The increasing availability of technology and knowledge makes use of biological agents more likely than ever before, posing a significant threat to national security. In modern times, biohazard challenges should be expected to increase as biotechnology develops. This creates threats to state entities whose main task is to ensure the security of their citizens. State actors are also actively working in the field of advanced biological weapons. In 1983, the former Soviet Union introduced the first genetically modified agent into its covert offensive program. This agent was a highly virulent strain of *Francisella tularensis*, the bacteria responsible for tularemia. The former Soviet Union's biological warfare program was one of the largest and most advanced state-sponsored programs in history[8].

The Centre for the Study of Existential Risk at Cambridge University has released a report stating that governments worldwide have not adequately prepared for potential threats such as futuristic bioweapons that utilize Artificial Intelligence (AI) and genetic manipulation. These weapons could selectively target specific DNA and eliminate entire races while leaving others unaffected[9].

What Are Genetically Engineered Bioweapons?

Genetically engineered bioweapons are a form of biotechnology used to create or modify genetic material of organisms, such as bacteria or viruses. This type of weapon is designed to use targeted biological agents that can cause physical and psychological harm to humans, animals, plants, and other living organisms. Genetically engineered bioweapons have the potential to cause serious damage to entire populations due to their highly infectious nature and the ease with which they can spread throughout an area. The idea of using bioweapons as a form of warfare has been around for centuries; however, modern advancements in genetic engineering technology have made them much more dangerous than ever before.

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[7] A. Garcia-Guerra, T. L. Dunwell, S. Trigueros, *Nano-Scale Gene Delivery Systems: Current Technology, Obstacles, and Future Directions,* "Current Medicinal Chemistry" 2018, Vol. 25, No 21, pp. 2448-2464.

[8] Zilinskas R. A., *The Soviet Biological Weapons Program and Its Legacy in Today's Russia*, National Defense University Press, Occasional Paper No 11, Washington DC 2016, pp. 15-16.

[9] *Policy Series Managing Global Catastrophic Risks Part 1 Understand,* 2023, <https://static1.squarespace.com/static/5d2f07e4d3a92c00016f1eff/t/5d511f66567c8a0001b01da1/1565597543527/Policy+Series_Managing+Global+Catastrophic+Risks_Part+1_Understand_web.pdf> (30.10.2024).

According to Michael Knutzen from United States Naval Institute, next-generation bioweapons are the most serious. Unlike traditional bioweapons, which most states have abandoned as unreliable, synthetic bioweapons (SBWs) are weaponized biological threats modified through synthetic biology for novel effects, mechanisms or processes. Unshackled from natural biology, SBWs possess characteristics engineered to target populations or individuals, through socially transmitted rather than kinetic means. Although each of the military services and the entire U.S. population could be at risk from SBWs, the nature of the Sea Services' operations – far from home but necessarily dependent on local goods and services in forward-deployed location – places them at particular risk[10].

Gryphon Scientific research explored the potential impact of novel biotechnologies, such as synthetic biology, on traditional steps involved in weaponizing biological agents. The presenter highlighted that agents created using synthetic biology could possess greater potency, increased growth potential, improved environmental durability, enhanced transmissibility, and the ability to overcome host resistance. However, utilizing synthetic biology tools may not be the optimal approach to achieve these goals due to inherent limitations (such as insufficient knowledge) and external factors like the requirement for ongoing testing throughout the development of weapon products[11].

The effects caused by genetically engineered bioweapons can be extremely destructive, ranging from disease outbreaks and death tolls to long-term environmental damage. These weapons also pose a major security risk as their manufacture and distribution requires sophisticated means. According to biological warfare expert Dr. Steven Block, genetically engineered pathogens *"could be made safer to handle, easier to distribute, capable of ethnic specificity, or be made to cause higher mortality rates"*[12].

It is also worth mentioning that genetically modified pathogens can be used beneficially for the humanity. It has been shown through increasing evidence that genetically engineered bacteria (GEB) can effectively treat various illnesses in clinical trials[13].

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[10] U.S. Naval Institute, *Synthetic Bioweapons Are Coming*, 2021, <https://www.usni.org/magazines/proceedings/2021/june/synthetic-bioweapons-are-coming> (30.10.2024).

[11] M. Imperiale, P. Boyle, P. A. Carr et al., *Biodefense in the Age of Synthetic Biology*, The National Academies Press, Washington DC 2018, p. 174.

[12] M. J. Ainscough, *Next Generation Bioweapons: The Technology of Genetic Engineering Applied to Biowarfare and Bioterrorism*, Air Univ Maxwell AFB AL 2002, p. 27.

[13] Liu Y. et al., *Genetically Engineered Bacterium: Principles, Practices, and Prospects*, "Frontiers in Microbiology" 2022, No 13, <https://www.frontiersin.org/articles/10.3389/fmicb.2022.997587> (30.10.2024).

Classes Of Genetically Engineered Pathogens

The U.S. government enlisted the help of the JASON group, consisting of academic scientists, to provide technical advice in a study conducted in 1997 aimed at identifying potential uses and dangers associated with advanced biological warfare agents. The research produced six major categories of genetically modified pathogens that have the potential to cause significant harm to society[14].

These groups consist of:

1. binary biological weapons;
2. designer genes;
3. gene therapy as a weapon;
4. stealth viruses;
5. host-swapping diseases;
6. designer diseases.

<u>Binary biological weapons</u> - while creating binary biological weapons used to pose a challenge, advancements in engineering and starting up complete genomes have transformed the process. Utilizing contemporary synthetic biology methods, it is possible for someone to design and manufacture two connected viruses that are not deadly on their own. After the host gets infected with both viruses, the combination of the two strains results in the creation of potent and contagious viruses[15]. This raises concerns about non-state actors developing binary weapons by keeping the components apart during transportation and assembling them before deploying them as biological weapons. With the advancement and proliferation of technology, individuals may have the capability of modifying bacterial and viral genes through a basic home laboratory system, without the need of extensive expertise or training.

<u>Designer genes</u> - The human genome project's triumph laid the foundation for comprehending the intricate genetic data's essence and composition, which could be employed to design novel biological entities. The future could see designer genes being utilized as the deadliest bioweapon, with countries interested in developing lethal weapons openly accessing genomic sequence databases to select the desired genes for designing. According to an evaluation, the continuously growing microbial genome databases offer a comprehensive list of potential genes associated with pathogenicity, virulence, adhesion and colonization of host cells, immune-response evasion, and antibiotic resistance,

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[14] J. O. Almosara, *Biotechnology: genetically engineered pathogens*, Air Univ Maxwell AFB AL 2010, pp. 8-18.

[15] K. Hummel, *Engineered Pathogens and Unnatural Biological Weapons: The Future Threat of Synthetic Biology*, Combating Terrorism Center at West Point 2020, <https://ctc.westpoint.edu/engineered-pathogens-and-unnatural-biological-weapons-the-future-threat-of-synthetic-biology/> (30.10.2024).

allowing the selection of the most lethal combinations[16]. The mechanism targets the unique proteins found in the immune system of certain ethnic or racial groups. By targeting specific molecular tags within cells, a synthetic or altered biological agent could disable the ability to fight disease, similar to how HIV attacks helper T cells. This would leave the entire population vulnerable to opportunistic infections[17].

Gene therapy as a weapon - Recombinant DNA technology, also known as gene splicing, involves inserting a single gene into an organism to modify its genetic characteristics. This technique has been used to splice genes responsible for insulin production into plasmid DNA, which can infect bacteria. As a result, a significant quantity of insulin can be produced for medicinal purposes. However, it is important to consider the potential dangers of this biotechnology because genes can be manipulated to create an infectious state that could be used as a bioweapon. There are also many potential threats resulting from the implementation of genetic therapy of people for military purposes. Such therapy would create a super soldier whose physical and mental parameters would be significantly different from those of a natural human being. The justification for using genetically modified super soldiers in warfare requires scrutiny under the law, as some of the involved technologies may violate international humanitarian principles and fail to meet ethical standards. The emergence of genetically modified soldiers would have dire international consequences[18].

Stealth viruses - A stealth virus is a type of viral infection that enters human cells undetected and remains inactive for a prolonged period. However, the virus can be triggered to become active and cause illness by an external stimulus[19]. This process can occur also naturally, according to Centers For Disease Control And Prevention "shingles is caused by varicella zoster virus (VZV), the same virus that causes chickenpox. After a person recovers from chickenpox, the virus stays dormant (inactive) in their body. The virus can reactivate later, causing shingles[20]." It's important to note that most viruses do not cause disease. As a biological weapon, a stealth virus could infect a

[16] C. M. Fraser, M. R. Dando, *Genomics and Future Biological Weapons: The Need for Preventive Action by the Biomedical Community*, "Nature Genetics 29" 2001, No. 3, pp. 253-256.

[17] J. M. Appel, *Is All Fair in Biological Warfare? The Controversy over Genetically Engineered Biological Weapons*, "Journal of Medical Ethics" 2009, Vol. 35, No 7, pp. 29–32.

[18] K. McCarty, *Building a Better Soldier: Human Enhancement Technologies in the 21st Century*, "Paideia" 2014, No. 1.

[19] Ya. Lakota, *Sovremennyye biologicheskiye ugrozy – tam, gde proshlyye prognozy vstrechayutsya s budushchim* (angl.), "Vestnik voysk RHB" 2020, Vol.4, No 4, pp. 421-430.

[20] *How Shingles Spreads*, CDC, 2022, No 28, <https://www.cdc.gov/shingles/about/transmission.html> (30.10.2024).

population's genome without detection. Subsequently, the virus may be triggered among the intended group.

Host-swapping diseases - To infect a new host, pathogens frequently need to adjust by modifying their approach, such as changing the receptors they target on cells, evading the immune system, or guaranteeing transmission through the new host. Viruses, in particular, have limited options to accomplish this and frequently rely on identical sequence alterations when infecting a specific host[21]. The exchange of diseases among hosts is now considered as potential biological warfare hazard. Additionally, the Center for Disease Control and Prevention has categorized it as a high-priority agent in Category A[22].

Designer diseases – Advancements in cellular and molecular biology have brought us close to the possibility of designing a disease conceptually and then engineering a pathogen to achieve the intended outcome. The possibility of creating designer diseases using detailed knowledge of biochemical signaling pathways falls under the category of designer diseases. These are considered as new threats that are linked to synthetic biology. Synthetic biology is an interdisciplinary field that incorporates biotechnology, evolutionary biology, molecular biology, systems biology, biophysics, computer engineering, and genetic engineering[23]. Scenarios where new diseases may be created in a laboratory setting, without the proper safety protocols or oversight, are possible. This means that anyone with sufficient resources and knowledge could potentially engineer a deadly virus that not only has the capability to cause widespread pandemic outbreak but also resists conventional treatments. Illicitly attempting to obtain bioagents for malicious purposes, including their production, is referred as black biology. This involves manipulating existing agents in both genomic and postgenomic fields, as well as allowing for synthetic biochemistry with cell-free manufacturing phases[24].

CRISPR Genome Editing

According to Broad Institute "CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, which are the hallmark of a bacterial defense system that forms the basis for CRISPR-Cas9 genome editing

[21] B. Longdon, M. A. Brockhurst, C. A. Russell et al., *The Evolution and Genetics of Virus Host Shifts*, "PLoS Pathogens 10" 2014, No 11.
[22] *CDC - Bioterrorism Agents/Diseases (by Category)*, "Emergency Preparedness & Response" 2019, <https://emergency.cdc.gov/agent/agentlist-category.asp>.
[23] *About genomics*, "Synthetic Biology" 2022, No 14, <https://www.genome.gov/about-genomics/policy-issues/Synthetic-Biology> (30.10.2024).
[24] M. E. Kambouris, *Chapter 8 - Bio-Offense: Black Biology*, [in:] *Genomics in Biosecurity*, ed. M. E. Kambouris, Translational and Applied Genomics, Academic Press 2022, pp. 109-126.

technology. In the field of genome engineering, the term “CRISPR” or “CRISPR-Cas9” is often used loosely to refer to the various CRISPR-Cas9 and -CPF1, (and other) systems that can be programmed to target specific stretches of genetic code and to edit DNA at precise locations, as well as for other purposes, such as for new diagnostic tools. With these systems, researchers can permanently modify genes in living cells and organisms and, in the future, may make it possible to correct mutations at precise locations in the human genome in order to treat genetic causes of disease. Other systems are now available, such as CRISPR-Cas13’s, that target RNA provide alternate avenues for use, and with unique characteristics that have been leveraged for sensitive diagnostic tools, such as SHERLOCK”[25].

We are already seeing numerous applications of that technology in various industries, ranging from food safety to drug discovery[26]. Most other gene editing capabilities are now immediately obsolete due to the implementation of CRISPR, which signifies a novel advancement in synthetic biology. The progress made in molecular biology has enabled the application of gene-editing tools to modify the genome and investigate the functional effects of genetic modifications. CRISPR technology is becoming increasingly popular for treating genetic and pathogenic conditions. One day, a variation of CRISPR may be utilized to rectify cancer mutations in tumor cells[27].

CRISPR-edited organisms can also be used for military purposes such as early warning systems or bioremediation in hazardous environments[28][29]. By drastically reducing costs and time frame needed to develop advanced defense technologies, CRISPR genome editing could become a game changer in national security field. However, it has been suggested that CRISPR could be used to improve or create new bioweapons, which would put both civilian and military personnel at risk. By means of a synthetic gene drive, a mutation can

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[25] *Questions and Answers about CRISPR*, Broad Institute, 2014, <https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/questions-and-answers-about-crispr> (30.10.2024).

[26] *How CRISPR Is Changing Cancer Research and Treatment - NCI*, cgvBlogPost, 2020, <https://www.cancer.gov/news-events/cancer-currents-blog/2020/crispr-cancer-research-treatment> (30.10.2024).

[27] K. Naidu, G. Hariprabu, M. Sathya et al., *CRISPR/Cas9 in Cancer Therapy: A Review with a Special Focus on Tumor Angiogenesis*, "International Journal of Biological Macromolecules" 2021, No 192, pp. 913-930.

[28] H. Bahrulolum, H. Tarrahimofrad, F. N. Rouzbahani et al., *Potential of CRISPR/Cas System as Emerging Tools in the Detection of Viral Hepatitis Infection*, "Virology Journal" 2023, Vol 20, No 1, p. 91.

[29] S. Sahoo, S. P. Routray, S. Lenka et al., *CRISPR/Cas-Mediated Functional Gene Editing for Improvement in Bioremediation: An Emerging Strategy*, [in:] *Omics Insights in Environmental Bioremediation*, ed. V. Kumar, I. S. Thakur, Singapore: Springer Nature 2022, pp. 635–664.

be rapidly disseminated throughout a population, which could modify vectors to spread diseases that affect humans or eliminate crucial organisms[30].

The ability of CRISPR-type gene editors to modify neural phenotypes that impact cognition, emotion, and behavior directly in the brain is noteworthy. Accurately targeting specific genes in the brain could allow for the modulation of important aspects of physiological function, cognition, and behavior, both in a generalized and specific manner[31]. This creates very wide possibilities for the development of advanced neuroweapons with seriously threatening military potential. Current policy and regulations may not sufficiently address or cover the use of these tools, however studies on reversing the effects of CRISPR have been made. An article in the MIT Technology Review highlighted laboratories that are searching for natural proteins capable of disabling gene edits caused by CRISPR, known as anti-CRISPR molecules[32].

National Security And Biological Threats

National security is a multifaceted construct that encompasses various dimensions of statehood, including military, economic, political, and societal aspects. At its core, national security refers to the measures adopted by a nation-state to protect its territorial integrity, sovereignty, and citizens from external and internal threats that undermine its stability and well-being. National security is not a static concept but rather evolves with the changing geopolitical landscape and the emerging challenges facing the state. According to Segun Osisanya "*National security has been described as the ability of a state to cater for the protection and defence of its citizenry*"[33]. The field of biodefense represents a critical component of national security interests, in light of the complex and multi-faceted threats that have emerged in recent times. In order to address this challenge, biodefense research must adopt a comprehensive approach that encompasses both preventative and reactive measures.

As part of his annual Worldwide Threat Assessment report to the U.S. Congress in February 2016, James Clapper, the former Director of National

[30] D. Willingham, *A Fresh Threat: Will CAS9 Lead to CRISPR Bioweapons?*, "Journal of Biosecurity, Biosafety, and Biodefense Law" 2018, Vol. 9, No 1.
[31] D. DiEuliis, J. Giordano, *Why Gene Editors Like CRISPR/Cas May Be a Game-Changer for Neuroweapons*, "Health Security" 2017, Vol. 15, No 3, pp. 296–302.
[32] A. Regalado, *The Search for the Kryptonite That Can Stop CRISPR*, "MIT Technology Review" 2019.
[33] *National Security versus Global Security*, United Nations, accessed June 5, 2023, <https://www.un.org/en/chronicle/article/national-security-versus-global-security>(30.10.2024).

Intelligence for the United States, identified gene editing as a global threat[34]. The imperative to safeguard the populaces from the effects of biologically engineered weaponry should become a paramount concern for states in contemporary times. The potential for irreparable harm and devastation to both human health and ecosystems is tremendous, necessitating robust preventative measures by governments.

Countering biological threats has become a vital issue in the national security of The United States of America which was included in the memorandum from 18th October 2022. According to the document "*Countering biological threats, advancing pandemic preparedness, and achieving global health security are top national and international security priorities for the United States. Nearly all executive departments and agencies contribute to the biodefense mission of the United States Government*.[35]"

The threat that biological weapons pose to national security is immense. Such weapons can be transmitted through air, water or food supplies, making them extremely difficult to detect and defend against. They allow terrorists to spread deadly pathogens undetected by authorities, using the population as unwitting carriers of dangerous viruses or bacteria. This means a single attack could potentially affect entire countries in ways that are both unpredictable and devastating. In addition, the ability for these weapons to be produced with relatively cheap resources and minimal expertise is a major concern for governments trying to protect their citizens from biological attacks. An individual terrorist cell operating out of a small laboratory could cause disruption on a massive scale with just a few vials of bacteria or virus cultures.

There are many possible scenarios for the use of biological weapons to threaten national security. Genetic engineering opens up many new risks as it could be used to make biological agents such as viruses and bacteria far more potent. Such modifications could make it much easier for malicious actors to cause serious harm on a massive scale. According to Public Health Reports there are two primary methods for potential biological warfare - generating clouds of harmful aerosols above urban centers, and polluting water, food, or the air inside strategic buildings through sabotage. The former aims to cause significant casualties in densely populated areas, while the latter targets specific groups to disable crucial individuals and industries or to provoke panic and

[34] J. R. Clapper, *Worldwide Threat Assessment*, "Testimony to the House Permanent Select Committee on Intelligence" 2014, No 201, p. 3.

[35] N*ational Security Memorandum on Countering Biological Threats, Enhancing Pandemic Preparedness, and Achieving Global Health Security*, The White House 2022, <https://www.whitehouse.gov/briefing-room/presidential-actions/2022/10/18/national-security-memorandum-on-countering-biological-threats-enhancing-pandemic-preparedness-and-achieving-global-health-security> (30.10.2024).

erode public morale[36].The use of biological warfare agents presents a unique challenge for emergency responders and healthcare providers. As opposed to dealing with physical injuries caused by conventional weapons, those exposed may not show any symptoms until days or weeks after exposure which can make diagnosis and treatment difficult. Furthermore, treatments must target pathogens that could potentially mutate in order for them to remain effective over time. In order to protect ourselves from a biological attack, it is important to have a comprehensive understanding of its characteristics. The nature of a biological attack can vary depending on the type of bioagent utilized, its method of dispersal, and the target of the attack. It is possible for biological weapons to be used against humans, livestock, or crops.

Deployment of Anti Agricultural Pathogens - The use of offensive biological weapons against animals and plants is an incredibly concerning issue that many countries have pursued, developed, and deployed in the past. Biological agents can cause harm to livestock, crops, or even humans if used maliciously. This is why it's so important for the world to be aware of and actively combat the potential use of such weapons by terrorist groups or hostile nations[37]. Every major state with a biological warfare program has devoted considerable resources to researching and developing agents that can be used against food crops and other plants. This is due to the fact that plants are so essential for human life. They provide us with food, clothing, shelter, medicines, transport fuels and more. For this reason, it is thought that if an enemy was able to attack our plant supply it could have catastrophic effects on our population’s ability to survive. Even if the attack wasn’t lethal initially, the long-term consequences of reducing or eliminating our food source would be dire indeed. As such, military planners around the world view anti-plant capabilities as an important component of any successful biological warfare strategy[38]. The challenge for a terrorist group after obtaining an anti-agricultural weapon is to spread it widely enough to harm the industry that occupies a significant portion of the country's interior. Since crops require vast areas of land to grow, they are cultivated over thousands of square miles. In contrast, modern animal farms are massive operations with several hundred thousand animals in one location. As a result, targeting crops versus targeting livestock or poultry requires markedly different techniques due to the distinct concentrations of these two types of targets. This type of attack has the

[36] A. Langmuir, *The Potentialities of Biological Warfare against Man. An Epidemiological Appraisal*,” Public Health Reports, Washington DC: 1896, 1951, Vol. 66, No 13, pp. 387-399.

[37] *Agricultural Biological Warfare: An Overview | Office of Justice Programs*, accessed June 17, 2023, <https://www.ojp.gov/ncjrs/virtual-library/abstracts/agricultural-biological-warfare-overview> (30.10.2024).

[38] *Agricultural Biowarfare and Bioterrorism,* 2023, <https://www.iatp.org/sites/default/files/Agricultural_Biowarfare_and_Bioterrorism.htm> (30.10.2024).

potential to cause disease outbreaks that can lead to significant economic consequences in both scenarios. Furthermore, the lack of disincentives against the use of anti-agricultural weapons by terrorists further increases the probability of their deployment. The use of a zoonotic agent by a terrorist group would result in a heightened consumer response. The terrorists could avoid fatalities by notifying authorities before the animal products are consumed by humans. By proving that they contaminated a herd of animals and alleging that others have been contaminated as well, the terrorists could inflict an economic catastrophe on the meat or dairy industry.

Biological Threats Against Water Supply Systems - Despite the rapid improvement of detection methods for identifying deliberate contamination of water systems, the primary sign that a contamination event has taken place is likely to be a shift in disease trends and patterns, and potentially a widespread outbreak of waterborne illness within the community. As a result, an elevated number of patients seeking medical attention for unexplained or unusual sickness or injury may be the first indication of a terrorist attack. Aflatoxins, botulinum toxins, and ricin are examples of biological toxins that have been converted into weapons. It is also possible that other biotoxins have been weaponized. Studies indicate that the natural production of microcystins in stagnant water bodies can generate sufficient biotoxin to infect human populations if these water bodies are used as sources of public drinking water[39]. Under appropriate circumstances, drinking water could be at risk from the majority of biotoxins. Nevertheless, some biotoxins either lack a recognized infectious pathway through ingestion or cannot endure in water[40]. Given the current war on terrorism, it is imperative to reevaluate the importance of water system infrastructure and protection. Additionally, efforts should be made to ensure the provision of high-quality drinking water, which is something that should already be a priority. Protecting physical water storage and transmission structures that cater to large populations should be given top priority. Structures such as dams, aqueducts, and pumping stations that transport water over long distances are particularly susceptible to physical damage and would be challenging to replace[41].

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[39] P. L. Meinhardt, *Water and Bioterrorism: Preparing for the Potential Threat to U.S. Water Supplies and Public Health*, "Annual Review of Public Health" 2005, No 26, pp. 213-237.

[40] *Medical Issues Information Paper No. IP-31-017: Biological Warfare Agents as Potable Water Threats | Office of Justice Programs*, 2023, <https://www.ojp.gov/ncjrs/virtual-library/abstracts/medical-issues-information-paper-no-ip-31-017-biological-warfare> (30.10.2024).

[41] R. G. Luthy, *Bioterrorism and Water Security*, "Environmental Science & Technology" 2002, Vol. 36, No 7, pp. 123A-123A.

Biological warfare (BW) aerosol attacks - Aerosol sprays are considered as the most effective method for delivery, and are often used by terrorists and military groups. This is due to the small particle size (1-5 μm) which allows for efficient delivery to the air sacs of the lungs. Aerosol generators can create particles of optimal size and deliver them through a fixed point source (such as sprayers) or a line source (such as a moving vehicle, airplane, or boat). Other methods of delivery include food and water contamination, conventional explosive munitions, and covert injections. Biological warfare agents in aerosol form have the potential to spread incapacitating or lethal doses across vast regions[42]. The transmission of plague can occur through aerosols or by breathing in droplets of sputum from patients who are coughing. If left untreated, this can lead to the rapid development of a severe form of pneumonia and result in death within 2-3 days. If used deliberately by terrorists, they may release the disease through aerosols or infected fleas. Due to its lethality, plague is considered as deadly agent.

Infected Animal Vector dissemination - If an aggressor were to use local animal reservoirs and vectors to spread a zoonotic pathogen, the situation would become extremely complex due to the challenge of distinguishing between natural and artificial factors in the unique geographic distribution of epidemics[43]. In the event of a bioterrorist attack, public health officials may have to deal with the potential of the agent remaining in the environment for an extended period. Anthrax spores have been known to survive in soil for years. As a result, keeping an eye out for sporadic cases in animal populations like livestock could reveal areas of exposure. While dogs and cats are not as susceptible to B. anthracis as ruminants, their proximity to humans and contact with soil could make them useful indicators. For instance, a Labrador retriever developed anthrax after hunting in a newly plowed field[44]. It can be inferred from these findings that there is a requirement for taking specific measures to be prepared for biological agent attacks. One of the primary steps is to enhance the exchange of information between professionals in animal health and human health domains, which would enable prompt identification of critical events.

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[42] R. Agarwal, S. K. Shukla, S. Dharmani et al., *Biological Warfare-an Emerging Threat*. "JAPI" 2004, Vol. 52, No. 9, pp. 733-738.

[43] R. Grunow, E.-J. Finke, *A Procedure for Differentiating between the Intentional Release of Biological Warfare Agents and Natural Outbreaks of Disease: Its Use in Analyzing the Tularemia Outbreak in Kosovo in 1999 and 2000*, "Clinical Microbiology and Infection" 2002, Vol. 8, No 8, pp. 510-521.

[44] P. Rabinowitz, Z. Gordon, D. Chudnov et al., *Animals as Sentinels of Bioterrorism Agents*, "Emerging Infectious Diseases" 2006, Vol. 12, No 4, pp. 647-652.

Preparedness For The Potential Biological Threats

With natural disasters, accidents, and malicious attacks all posing risks to security; it is essential that state actors are prepared for any incident that may occur. The complexity of the nature of hazards caused by biological agents, forces governments to take preventive measures that could protect the civilian population and national security. The development of biological sciences forces quick adaptation to the changing security environment, governments around the world must take preventive measures to protect their civilian populations. In order to do this, they must be aware of the various forms of biological agents that can cause harm. This includes bacteria, viruses, fungi, parasites and toxins – both naturally occurring ones as well as those created in a laboratory environment. Governments must also be prepared for potential outbreaks due to natural disasters or deliberate attacks with weapons of mass destruction. In addition to understanding what type of biological agents may pose a hazard, government agencies must have systems in place for early detection so that countermeasures can be taken quickly. This means regular monitoring should occur through surveillance methods such as laboratory tests on blood samples and other specimens collected from people who may have come into contact with the agent in question. Moreover, advanced early warning systems are essential to broadly identify and counter biological threats from different sources than human hosts. These systems can include the use of biological sensors such as bio-threat detectors, which are able to detect a wide range of hazards (for example pathogenic microorganisms in air or food). Depending on methods of operations and detection, such systems can be deployed on multiple levels to counter hybrid biological threats.

Electrochemical Biosensors Detection System - Detecting and identifying biological warfare agents is a significant obstacle for various government agencies, such as military and health departments. It is crucial to have dependable and precise identification of the microorganisms from various sampling locations like air, water, or soil. As a result, research has been done to develop methods to detect these agents in the environment. One example of this research is the development of biological sensors that can detect the presence of specific pathogens or viruses. A biosensor is a small analytical device that identifies and measures a specific substance. It comprises three components:

1. a biological receptor (DNA, antibodies, enzymes, cells) that detects the target molecule;
2. a transducer that interprets the biological recognition event and converts it into a measurable signal;
3. a display for signal processing.

Biosensors have gained popularity due to the drawbacks of existing methods, including high expenses, the need for skilled personnel, and lengthy response times. These issues are not ideal for prompt diagnosis in the early stages[45]. The biosensor's selectivity for the target analyte is provided by a biorecognition molecule, which can be an enzyme, antibody, DNA sequence, peptide or microorganism. This allows the biosensor to identify the molecule of interest from a mixture of other molecules. An electronic signal is generated by the signal transducer, which measures the extent of the biorecognition event. The output can be sent to the end user and common transducers include amperometric electrodes, optical waveguides and mass sensitive piezoelectric crystals[46]. These sensors are designed to quickly identify any potential threats and provide early warning so that precautionary measures can be taken. In addition, advances in technology have allowed scientists to analyze samples from extremely small areas with great accuracy. This means even if just trace amounts of an agent are present it can still be detected and identified quickly. However, detecting and identifying biological warfare agents is not only difficult but also highly expensive due to the sophisticated equipment needed for accurate results. With the development of nanotechnology, biosensors are more advanced and improved in terms of their sensitivity, miniaturization and mobility. Scientists also have recently shifted their attention towards nanomaterials and nanoparticles as beneficial resources for creating electrochemical biosensing layers that may exhibit improved performance[47].

Various electrochemical biosensors have been created utilizing the following methods[48]:

1. Immunosensors;
2. PCR (DNA-based sensors);
3. Bacteria or whole cell sensors;
4. Enzyme sensors.

Immunosensors - Biosensors can be categorized based on either their bioreceptor component or the transduction mechanism employed. In cases where antibodies serve as the bioreceptor, these biosensors are known as immunosensors. Antibodies are a crucial bioreceptor for detecting specific

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[45] J. Leva-Bueno, S. A. Peyman, P. A. Millner, *A Review on Impedimetric Immunosensors for Pathogen and Biomarker Detection*, "Medical Microbiology and Immunology" 2020, Vol. 209, No 3, pp. 343-362.

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[47] E. Švábenská, D. Kovář, V. Krajíček et al., *Electrochemical Biosensor for Detection of Bioagents*, "Int. J. Electrochem. Sci" 2011, No 6, pp. 5968-5979.

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analytes due to their highly precise non-covalent interaction with antigens[49]. The operation of impedimetric immunosensors involves utilizing antibodies or other affinity proteins like Affimers (affimer proteins are a kind of binding protein that can be utilized for investigating protein expression and function as an alternative)[50] or binding proteins as bioreceptors on a biosensor platform, which is subjected to electrochemical impedance spectroscopy.

PCR (DNA-based sensors) - The limitations of PCR-based methods are significant as they require prior knowledge of the sequence to be detected in a sample. Additionally, recent studies have shown more variability in genomic sequences than previously anticipated, further complicating the process[51]. A novel type of affinity biosensors for small molecular weight molecules can be created by integrating nucleic acid layers with electrochemical or optical transducers[52]. By immobilizing a single-stranded oligonucleotide on a transducer surface, DNA biosensors can recognize its complementary DNA sequence through hybridization, which forms a duplex known as a hybrid. This recognition event is then translated into an analytical signal by the transducer, which can be an electrochemical, optical, gravimetric, surface plasmon resonance-based or electrical device. Electrochemical biosensors are preferred over other measurement systems due to their fast, simple and cost-effective detection capabilities. Essentially, DNA biosensors convert the recognition of Watson Crick base pairs into a readable analytical signal[53].

Bacteria or whole cell sensors – They are utilized to detect whole bacterial cells, enabling the sensitive and early identification of bacteria without requiring any sample processing[54]. Particularly impedance-based systems, are emphasized due to their ease of miniaturization, lack of reagents, sensitivity, and affordability. Identifying bacteria is gaining significance in efforts to combat bioterrorism. Typically, traditional methods for identifying bacteria involve assessing the microorganism's physical characteristics and conducting experiments to determine its capacity to thrive in different environments using

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[49] C. J. van Oss, R. J. Good, M. K. Chaudhury, *Nature of the Antigen-Antibody Interaction: Primary and Secondary Bonds: Optimal Conditions for Association and Dissociation*, "Journal of Chromatography B: Biomedical Sciences and Applications, 6th International Symposium on Bioaffinity Chromatography" 1986, No 376, pp. 111-119.

[50] *What Are Affimers?*, News-Medical.net 2019, <https://www.news-medical.net/life-sciences/What-are-Affimers.aspx> (30.10.2024).

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[54] A. Ahmed, J. V. Rushworth, N. A. Hirst et al., *Biosensors for Whole-Cell Bacterial Detection*, "Clinical Microbiology Reviews" 2014, Vol. 27, No 3, pp. 631-646.

diverse growth mediums[55]. Modern methods of using biosensors make it possible to avoid time-consuming pathogen detection processes.

Enzyme sensors – Biosensors initially utilized enzymes as biocatalysts and they continue to be the prevailing choice. The oxidoreductases and hydrolases are the two essential categories of enzymes. The former facilitates the oxidation of substances with oxygen or nicotinamide adenine dinucleotide, while the latter catalyzes the hydrolysis of compounds[56]. Clark's and Lyons's publication on the oxygen electrode in 1956 marked the beginning of research into biosensors and amperometric transducers[57]. Authors presented a report at the Symposium of New York Academy of Sciences proposing a method to enhance electrochemical sensors by incorporating an enzyme transducer in the form of a membrane sandwich, based on their experiments. Although Updike and Hicks are often credited with its development and application to biosensors with entrapped enzymes, they actually worked on it later. They were the ones who introduced the glucose-specific enzymatic electrode, which was found to be more straightforward and reliable than Clark's version. These early studies paved the way for the successful advancement and eventual commercialization of amperometric biosensors[58].

Wide use and dissemination of modern biosensor technologies to quickly detect potential threats by state entities and private institutions would become a key component in the implementation of a broad and advanced biosecurity system. The government should ensure that its biosecurity system is able to detect and adress emerging biological threats in a timely manner. The public health sector needs to be capable of rapidly identifying, isolating, and containing potential biological threats.

Medical Intelligence In The Service Of National Security

Medical Intelligence is defined as "The product of collection, evaluation, and all-source analysis of worldwide health threats and issues, including foreign medical capabilities, infectious disease, environmental health risks,

[55] D. Ivnitski, I. Abdel-Hamid, P. Atanasov et al., *Biosensors for Detection of Pathogenic Bacteria*, "Biosensors and Bioelectronics" 1999, Vol. 14, No 7, pp. 599-624.
[56] J. Shah, P. Wilkins, *Electrochemical Biosensors for Detection of Biological Warfare Agents*, "Electroanalysis" 2003, Vol. 15, No 3, pp. 157-167.
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developments in biotechnology and biomedical subjects of national and military importance, and support to force protection"[59].

Medical intelligence (also called MEDINT) is crucial element of the national security system. It is an invaluable tool in the effort to prevent biological warfare threats. It involves the gathering and collation of data concerning the development, production, and stockpiling of chemical or biological agents that could be used as weapons. This knowledge helps to inform decision makers on best practices when it comes to protecting a nation from these potential threats. By monitoring military activities, researching new weapons technologies, and sharing information with other regions about potential developments in biowarfare capabilities, MEDINT can help protect citizens from the devastating effects of such threats.

As threats to global security continue to evolve, MEDINT allows for countries and organizations to monitor, assess, and respond quickly and effectively to potential health crises. In particular, it helps to understand how disease-causing agents such as viruses could spread across borders or within a specific population in order to mitigate the risk of infection or contamination. These efforts can also provide valuable information about which treatments are most effective against certain diseases so that healthcare professionals can prepare accordingly. Furthermore, MEDINT plays an important role in improving public health preparedness for natural disasters or major public health crises like pandemics by providing accurate forecasts on how a particular outbreak might spread and what areas would be affected first.

The most crucial tool for detecting global public health incidents, specifically the emergence of infectious diseases, is acknowledged to be surveillance. Surveillance not only aids in the detection of bioterrorism attacks but also provides valuable information for identifying and addressing emerging infectious diseases. Even though these epidemics are not linked to conventional bioterror agents, their impact on public health can be similarly concerning. In fact, many public health institutes within the United States have integrated global infectious disease surveillance into their strategic plan. The CDC, for example, has established its Emerging Infections Program[60].

Basic surveillance involves four main functions[61]:

1. identifying and reporting cases of disease in particular populations;
2. verifying and analyzing reported case data to detect outbreaks;

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[59] *Medical Intelligence Health Mil.*, "Military Health System" 2023, <https://www.health.mil/Reference-Center/Glossary-Terms/2020/09/17/Medical-Intelligence> (30.10.2024).

[60] *Emerging Infections Program Sites CDC - DPEI - NCEZID*, 2022, <https://www.cdc.gov/ncezid/dpei/eip/eip-sites.html> (30.10.2024).

[61] C. Castillo-Salgado, *Trends and Directions of Global Public Health Surveillance*, "Epidemiologic Reviews" 2010, Vol. 32, No 1, pp. 93-109.

3. responding promptly and effectively at the local and regional levels to enable national-level prevention and control of disease outbreaks;
4. offering epidemiological intelligence to aid in the long-term management of public health policies and healthcare programs.

Health care surveillance involves the ongoing and organized gathering, evaluation, understanding, and distribution of information. At first, public health surveillance was inactive and optional. When a patient was diagnosed with a reportable contagious illness, clinicians, hospitals, or laboratories would notify the local health department. The data would take time to move through local and state health departments. Although local agencies play a crucial role in surveillance, it requires the cooperation of many parties to execute it efficiently.

Global biological surveillance relies on passive surveillance as a crucial element. This method is cost-effective, simple to execute, and does not require advanced technology. Nevertheless, it may not be sufficient on its own to respond promptly and precisely to a biological threatening incident. Passive surveillance, when combined with other techniques, is most effective in promptly detecting the threat and implementing public health safety measures like preventive treatment or health promoting initiatives like awareness of the importance of personal hygiene on the prevention of bacterial infections[62].

Tracking emerging infectious disease threats is done through active surveillance, which involves actively collecting disease information from specific groups like sentinel medical providers or hospitals. These groups are then monitored over time to assess the impact of new public health initiatives and changes in disease incidence. The goal is to identify and monitor emerging infectious disease threats before they become widespread. This method is typically used to search for a specific disease and requires more public health resources and labor than passive surveillance[63].

For public health biosurveillance systems to be effective, they must possess three crucial elements: promptness, superior sensitivity and specificity, and regular data analysis. Early diagnosis is critical to the success of most treatments, making timely detection essential. Electronic collection and

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[62] E. C. Kaltenthaler, J. V. Pinfold, *Microbiological Methods for Assessing Handwashing Practice in Hygiene Behaviour Studies*, "The Journal of Tropical Medicine and Hygiene" 1995, Vol. 98, No 2, pp. 101-106.
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reporting of surveillance data have contributed significantly to enhancing detection as compared to manual methods[64].

Internet Biosurveillance - The early detection and awareness of infectious diseases in humans, animals, and plants, as well as chemical, radiological, and nuclear threats, is made possible through the use of unstructured data from various web-based sources in internet biosurveillance. The field has expanded to encompass social media, participatory sources, and non-text-based sources due to the rising amount of information and new media types available on the Internet. The extent of source coverage spans from local media in the vernacular to international media in widely read languages. Informal Internet sources are usually supplemented and verified by online official reporting sources[65]. The Internet biosurveillance process may differ, but typically involves[66]:

1. gathering and storing data from the Internet;
2. analyzing the data to generate information;
3. compiling the information into analyses;
4. distributing the analyses to end-users.

On the Internet, there is a variety of open-source and unorganized information related to disease outbreaks available in multiple languages. Several biosecurity intelligence systems are attempting to collect and analyze this data. Three of such systems are HealthMap, EpiSPIDER and BioCaster[67]. Biosurveillance systems play a crucial role in raising awareness about emerging infectious diseases and potential biological attacks.

Overall, Internet Biosurveillance systems have become indispensable in our global efforts to combat infectious diseases and secure populations against potential biological attacks. Their ability to gather real-time data from diverse sources enables timely responses by healthcare professionals and security agencies alike. With continued advancement in technology and increased collaboration between scientists worldwide, we can expect these systems to evolve further, providing even more comprehensive insights into emerging health threats.

Conclusions

The growing risks posed by modern biological threats have been discussed in this article. Moreover, the factors driving these increased risks are mainly beyond the control of individual states or even the international community.

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[65] D. M. Hartley, N. P. Nelson, R. R. Arthur et al., *An Overview of Internet Biosurveillance*, ”Clinical Microbiology and Infection" 2013, Vol. 19, No 11, pp. 1006-1013.
[66] *Ibidem.*
[67] *Ibidem.*

Advancements in biological sciences are promoted at both national and international levels for their material advantages. National governments and international organizations will face more challenging tasks in managing the risks resulting from these trends. The emergence of biosecurity on the international security agenda has opened up new possibilities for research and analysis. Despite of the growing attention given by governments, scholars, and analysts to the foreign policy and security implications of biological threats, there remains a substantial amount of work to be accomplished in the intersection of health and security. The appropriate implementation of modern biological threat prevention systems such as biosensors and medical intelligence tools plays a vital role in reducing the negative effects posed by biological agents to national security. Their integration into existing frameworks fosters efficient communication and collaboration among various stakeholders while enabling timely detection and response to potential threats.

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