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Biorisk management in global crises

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Overview:

This report summarizes biorisk challenges during global crisis and how they can be managed.

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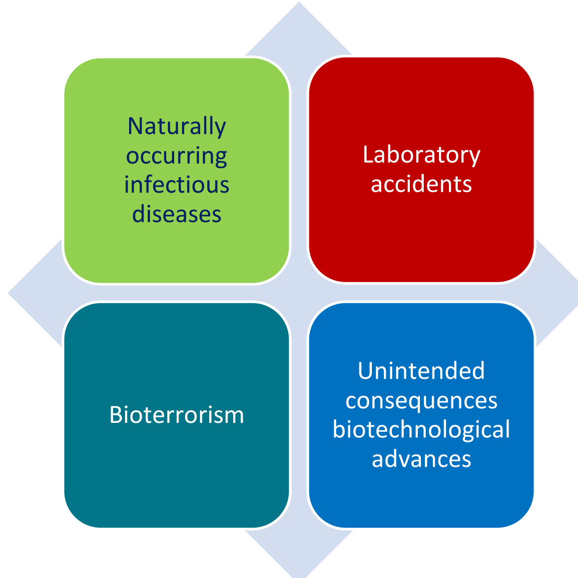
Contents

1. Executive Summary

Biorisk encompass a wide array of potential dangers, ranging from naturally occurring infectious diseases to laboratory accidents, bioterrorism, and the unintended consequences of biotechnological advances that can harm human, animal, and environmental health, all of which are discussed below. Biorisk *management* builds on two key pillars called biosafety and biosecurity.



Global crises vary in nature, and biorisk management becomes a key element during pandemics. For instance, COVID-19 provides an example of how biosafety and biosecurity risk management practices evolved rapidly to ensure progress in research is not limited by biorisks. The following are the main operational- and policy-level implications related to biorisk management for COVID-19.


Diagnostic chain

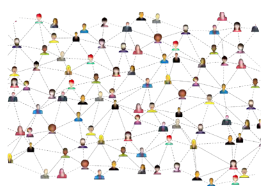

Treatment of patients


Research activities


Resource allocation


International cooperation


Risk communication


Capacity building

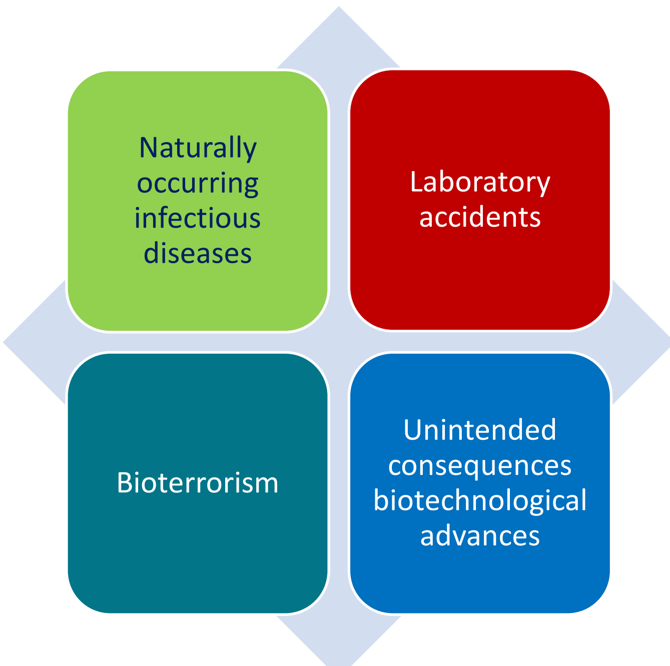

One health approach

Specialists trained in biosafety and biosecurity are essential for safeguarding public health and ensuring the responsible handling of biological materials. Swiftly delivered, specialist training of biosafety and biosecurity specialists focused on the relevant new pathogen is essential to prevent the future spreading of pathogens around the world. To achieve this and to protect nations around the world from a repeat of the COVID-19 pandemic, high-income countries must support lower-income countries in providing funding and expertise for such training whilst recognizing the need for mutual learning.

2. Biorisk – An introduction

The World Health Organization (WHO) defines biorisks as the risks associated with the handling and use of biological agents, materials, and substances to include prions, viruses, bacteria, fungi, parasites, genetically modified organisms (GMOs) and toxins that pose a threat to humans, animal, or plant health[1],[2].

Biorisk encompass a wide array of potential dangers, ranging from naturally occurring infectious diseases to laboratory accidents, bioterrorism, and the unintended consequences of biotechnological advances that can harm human, animal, and environmental health, all of which are discussed below.



Biorisks can be a source of global crisis situations like the SARS Cov2 or the Spanish influenza outbreaks clearly demonstrated[3],[4].

Biorisks can also accompany and aggravate risks in other crisis situations like war, famine or flooding due to secondary disease outbreaks following a breakdown of basic sanitary and health infrastructures in such situations.

Fig 1 – Overview of biorisks

Naturally occurring infectious diseases

Naturally occurring diseases are a subset of biorisks that arise without direct human intervention and that are caused by pathogens, which exist in the environment. They are primarily driven by ecological and evolutionary processes, often involving complex interactions between pathogens, hosts, and the environment[5]. Understanding the dynamics between biorisks and naturally occurring diseases is crucial for effective prevention, control, and management. Examples include zoonotic infections like Ebola, Hantavirus, and various influenza strains, which often spill over from animal reservoirs to humans.

The emergence of such diseases is influenced by several factors, including ecological changes, human behavior, and climate change. The destruction of natural habitats, intensified agriculture, and increased contact with wildlife heightens the risk of zoonotic disease spillover[6]. Climate change can also affect the distribution of vectors[7], leading to the spread of diseases like malaria and dengue fever to new regions[8].

Robust surveillance systems are fundamental for early detection of naturally occurring diseases. Monitoring the spread of diseases in wildlife, domestic animals, and humans can provide early warning signals, enabling rapid response measures[9].

Laboratory Accidents

Laboratories are essential hubs for scientific research and innovation. However, they also carry inherent risks, and laboratory accidents can have profound consequences for researchers and the broader community. These accidents can result in the release of hazardous biological agents, creating biorisks that threaten public health and the environment[10].

Accidents can occur due to various factors, including human error, equipment malfunctions, inadequate training, and lapses in safety protocols[11]. The consequences of such accidents can be severe, with potential impacts on public health, the environment, and the reputation of the scientific community.

Several high-profile laboratory accidents have underscored the significance of biorisks. One example is the 1978 smallpox outbreak in the United Kingdom, which resulted from the escape of the virus from a laboratory at the University of Birmingham[12]. Another is the accidental release of the SARS virus from a laboratory in Beijing in 2004[13].These incidents highlight the potentially far-reaching consequences of laboratory accidents involving highly infectious agents.

Bioterrorism

Bioterrorism involves the deliberate use of biological agents to harm individuals, populations, or the environment. It poses severe threats to human health, primarily through the intentional release of pathogens capable of causing deadly diseases. Bioterrorist attacks can result in significant mortality rates due to releasing highly virulent pathogens. History has witnessed several significant bioterrorism incidents. For example, the 2001 anthrax attacks in the United States, where letters containing Bacillus anthracis spores were mailed to individuals, resulted in several deaths and widespread panic[14]. Furthermore, bioterrorist attacks can create fear and panic among populations. The uncertainty surrounding the source of the outbreak and the potential for rapid disease transmission can lead to mass hysteria and strained healthcare systems the healthcare systems, leading to shortages of medical supplies, personnel, and treatment facilities[15]. This compromises the ability to provide effective care.

In another scenario, agriculture is a vital component of global food security, and bioterrorism can disrupt food production and supply chains by targeting crops or livestock, leading to substantial economic losses and food shortages[16]. Introducing harmful pathogens to agricultural systems can also have long-lasting effects on food production. Bioterrorism-related outbreaks in agriculture can result in international trade barriers, affecting both imports and exports of agricultural products[17]. This can have ripple effects on global food security. The potential of bioterrorism in impacting ecosystems and biodiversity e.g., through deliberate introduction of invasive species, is also considerable[18].

Biotechnology Advancements:

Biotechnological advances have unlocked incredible opportunities for scientific discovery, medical breakthroughs, and agricultural progress. However, they also introduce a complex web of biorisks that must be carefully managed to ensure the responsible development and application of these innovations[19].

Genetic engineering, the deliberate modification of an organism's genetic material, is a cornerstone of biotechnology. While it has yielded numerous benefits, it also poses specific biorisks. For example, genetic engineering can result in unintended genetic changes. When foreign genes are introduced into an organism's genome, they may disrupt existing genetic pathways, potentially leading to unintended consequences[20]. Furthermore, genetically modified organisms (GMOs) released into the environment can interact with native species, potentially leading to ecological disruption. The spread of GMOs and their potential impact on ecosystems is a significant concern, especially considering new powerful genetic technologies to spread genes in natural populations[21],[22]. Another risk factor relates to genetically modified crops used in agriculture that may contain allergens or other health-related substances. Ensuring the safety of genetically modified foods is essential to mitigate human health risks[23]. Furthermore, engineered organisms released into the environment may outcompete native species or disrupt ecological balance. The potential for unintended ecological consequences underscores the need for rigorous risk assessments.

A relatively new development in biotechnology advances is synthetic biology[24], an interdisciplinary field, that focuses on designing and constructing biological components, devices, and systems for various applications. Such techniques and tools can raise dual-use concerns (i.e. civilian and military use), including creating potentially harmful microorganisms, toxins or pathogens with enhanced virulence[25]. Decisions regarding the ethical implications of synthetic biology applications are central to responsible innovation[26].

Another new development are gene editing technologies, exemplified by CRISPR-Cas9, which have revolutionized genetic research and offer transformative potential. However, they also pose notable biorisks related, for example, to Off-Target Effects[27] and dual-use[28].

3. Biorisk management - an introduction

Biorisk management focuses on implementing preventive measures to reduce the risk of disease emergence. Effectively managing biorisk is therefore paramount to global health security and a key component of ethical considerations, for example, in the prevention of potential harm, responsible conduct of research and respect for human rights. Research conducted during pandemics is in a unique position to both reduce *and* increase biorisk during such times, and therefore active engagement with risk biorisk management approaches becomes critically important.

Biorisk management builds on two key pillars called biosafety and biosecurity, and in the following text, the term biorisk management is used as an umbrella term to cover both biosafety and biosecurity, respectively[29].

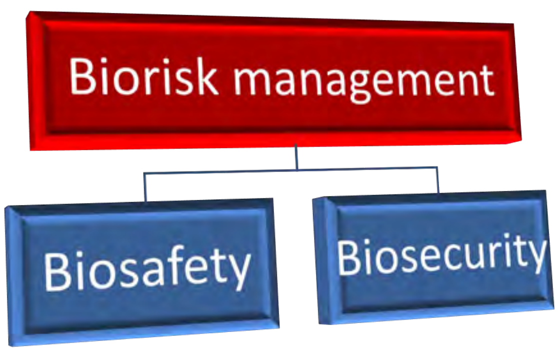


Fig 2 – Biorisk components

Biosafety relates to the safe working practices associated with the handling of biological materials, particularly infectious agents. It addresses containment principles, technologies and practices that are implemented to prevent unintentional exposure to pathogens and toxins or their accidental release[30].

Biosecurity refers to principles, technologies and practices that are implemented for the protection, control, and accountability of biological materials and/or the equipment, skills and data related to their handling. Biosecurity aims to prevent **unauthorized** access, loss, theft, misuse, diversion, or release[31].

Biorisk management is usually contextualised to various work environments like laboratory-, clinical or fieldwork involving pathogens and can be applied as an integrated framework of safety and security e.g., ISO35001 or through biosafety[32] and biosecurity risk management frameworks as in the WHO context. For example, biosafety in research and clinical laboratories is a well-developed discipline and includes[33]:

1. The identification and evaluation of potential biorisks associated with research activities, by thorough risk assessment[34].
2. The implementation of strict biosafety protocols, including the use of personal protective equipment (PPE), proper laboratory design, and containment measures to prevent the escape of pathogens.
3. The provision of comprehensive training for laboratory personnel on biorisk management, safety procedures, and emergency response protocols.
4. The establishment of mechanisms for reporting and investigating laboratory accidents promptly to learn from them and prevent future incidents , and
5. Regulatory Oversight that enforces regulatory frameworks and standards for laboratory biosafety to ensure compliance and accountability.

On the other hand, biosecurity in the context of emerging diseases[35] and especially in relation to laboratory biosecurity has become a critical aspect of modern scientific research while there are often overlaps with biosafety-focused risk management frameworks, some differences exist. As such, biosecurity risk management usually builds on[36]:

1. A risk assessment to identify and evaluate potential threats, vulnerabilities, and consequences associated with research. This process informs the development of tailored biosecurity measures and is structured differently than biosafety risk assessments.
2. The restriction of access to laboratories and their sensitive materials, allowing only authorized personnel with appropriate training access, and monitoring their activities closely.
3. The physical security of the laboratories by implementing physical barriers such as access controls, alarms, and secure storage to prevent unauthorized access to biological materials.
4. Personnel Security measures through thorough background checks, security clearances, and ongoing training to ensure that laboratory staff are trustworthy and aware of biosecurity protocols.
5. Inventory Control as laboratories must maintain strict inventory records to track the acquisition, use, transfer, and disposal of biological agents and toxins.

6. Laboratories must have clear and effective incident response plans in place, including procedures for reporting and mitigating security breaches or accidents.

4. Particular biorisk challenges during a global crisis

Global crises vary in nature, and biorisk management becomes a key element during pandemics. For instance, COVID-19 provides an example of how biosafety and biosecurity risk management practices evolved rapidly to ensure progress in research is not limited by unaccounted biorisks[37]. Other types of global crises should also have relationships to biorisk management.

War situations present a unique set of challenges, and when combined with biological risks, they become even more complex and potentially catastrophic[38]. Furthermore, the intersection of warfare and biological threats, such as bioterrorism and the use of biological weapons, poses significant and unique biorisk challenges. Bioterrorism, the intentional use of biological agents to cause harm, is a grave concern in war situations. The threat of biological weapons, whether by releasing deadly pathogens or toxins, is a biorisk challenge that has drawn considerable attention from the scientific community[39]. The potential consequences of a bioterror attack are far-reaching, with significant loss of life and long-lasting health impacts[40].

In addition, war situations can disrupt healthcare systems and infrastructure, leading to challenges in detecting, monitoring, and responding to biological threats. This is particularly evident in regions where armed conflict has caused displacement, overcrowding, and compromised healthcare access. Such conditions can exacerbate the spread of infectious diseases and hinder the delivery of critical medical care, making biorisk management a critical concern[41].

The scientific community also plays a pivotal role in addressing biorisk challenges in war situations. The concept of dual-use research, where scientific advancements intended for beneficial purposes can potentially be misused for harm, underscores the responsibility of scientists in war-affected regions. The need to balance conducting valuable research and preventing its misuse poses a significant challenge[42].

Earthquakes are natural disasters that can trigger a cascade of secondary hazards, including biological risks that often remain underestimated[43]. Effective biorisk management during and after earthquakes is essential to prevent outbreaks of infectious diseases and protect public health. For example, damage to water supply infrastructures can lead to contaminated drinking water, facilitating the spread of waterborne pathogens like Vibrio cholerae. Effective biorisk management includes providing access to safe water sources and implementing proper sanitary provisions[44].

Global warming, driven by anthropogenic activities such as the burning of fossil fuels and deforestation, has emerged as one of the most pressing environmental challenges of our time. While the direct consequences of global warming are well-documented, its link to biorisk management is a complex and increasingly recognized area as global warming has a significant impact on the distribution and behavior of disease vectors, such as mosquitoes and ticks[45]. Rising temperatures and altered precipitation patterns create favorable conditions for these vectors, expanding their geographical range and increasing the transmission of vector-borne diseases like malaria and dengue[46]. Effective biorisk management strategies must adapt to these changing disease dynamics.

Global warming contributes to the frequency and intensity of extreme weather events, including hurricanes, floods, and heatwaves. These events can disrupt public health systems, damage healthcare infrastructure, and increase the risk of infectious disease outbreak[47]. Biorisk management must consider the heightened vulnerabilities posed by climate-driven disasters.

5. COVID-19 as an example case study.

One of the most significant biorisk challenges in global crises is the emergence and rapid dissemination of infectious diseases[48]. Scientific research has identified a plethora of human-influenced factors contributing to this challenge, encompassing increased human mobility, urbanization, and climate change.[49]. The COVID-19 pandemic, triggered by the novel coronavirus SARS-CoV-2, serves as a vivid exemplar illustrating how a novel infectious disease can swiftly escalate into a global crisis, inflicting severe health[50], economic, and societal repercussions[51].

Biorisks and their concomitant considerations for biorisk management are pertinent across a wide range of contexts associated with COVID-19. This relevance extends to both operational and policy levels. While operational aspects primarily revolve around safeguarding the safety of stakeholders, the broader implications of biorisk management at the policy level may be less conspicuous but are equally pivotal.

For example, a search of PubMed entries related to biosafety and pandemics (Figure 3), as well as biosecurity and pandemics (Figure 4), reveals a remarkable tenfold increase in the number of papers published in peer-reviewed journals during the COVID-19 pandemic years in comparison to the pre-pandemic era. This demonstrates the critical importance of developing and sharing information on biorisk management strategies during pandemics.

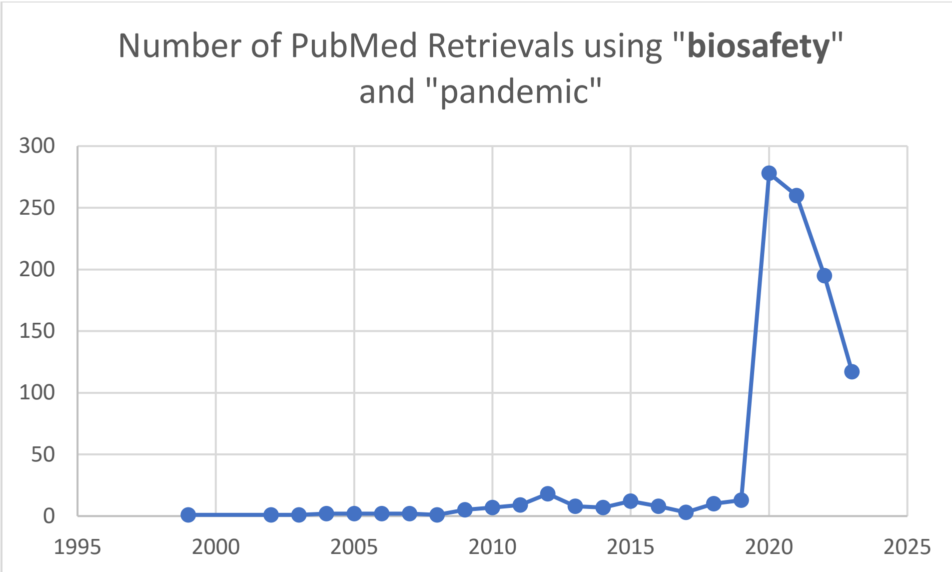


Fig 3 – Number of PubMed retrievals using "biosafety" and "pandemic

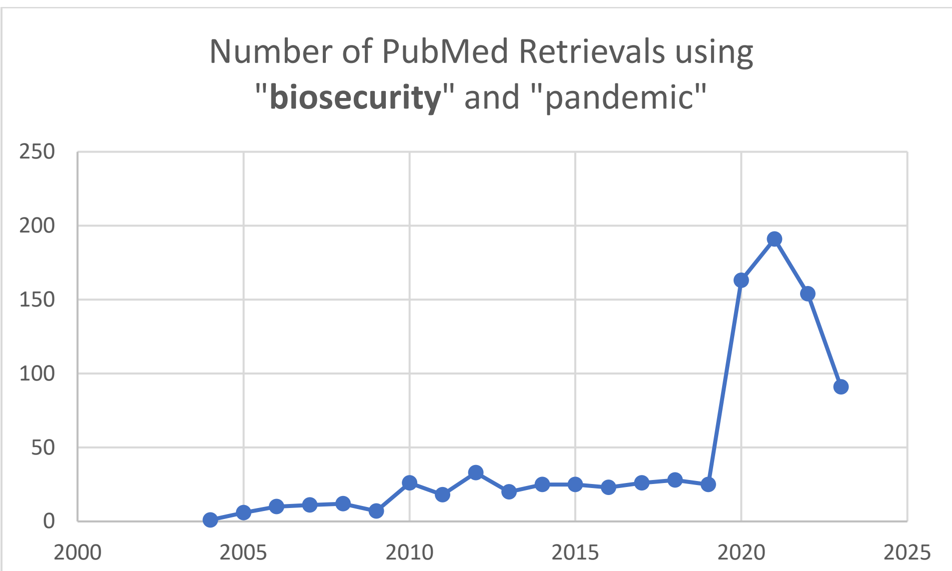


Figure 4: Number of PubMed entries related to biosecurity and pandemics

The following are the main operational- and policy-level implications related to biorisk management for COVID-19.

Figure 5: Number of PubMed entries related to biosafety and pandemics [pixabay photos]

Diagnostic Chain: Biorisk management in the context of COVID-19 encompasses a spectrum of biosafety measures in the diagnostic chain. These measures include safe techniques for sampling[52], secure specimen transfer[53], and precise analysis within laboratories[54,55], all of which are vital to curtail the risk of infection among healthcare workers and laboratory personnel.

Treatment of Patients: Biorisk management extends to the treatment of COVID-19 patients, necessitating strict isolation protocols, the use of personal protective equipment (PPE), and optimal ventilation within healthcare facilities to prevent viral transmission[56,57].

Research Activities: Biorisk management is integral to various COVID-19 research activities, spanning from the sequencing of the SARS-CoV-2 genome to animal testing and studies on viral evolution[58]. Each activity entails specific risk factors, necessitating tailored biorisk mitigation measures[59].

Resource Allocation: Policies governing biorisk management dictate resource allocation, including funding for research, the development of preventive measures, and preparedness strategies[60]. Ensuring adequate resource allocation is pivotal for an effective and coordinated response to emerging threats.

International Cooperation: Biorisk management policies are crucial in fostering international cooperation and facilitating sample and information sharing. This is particularly relevant due to the dual-use nature of the agent[61] and international investigations into the origin of the virus[62]. The consideration by the WHO and others[63] that the agent might have originated from a national laboratory leak or natural national outbreak underscores the need for international collaboration[64].

Risk communication: Vaccine hesitancy, driven by misinformation and mistrust, poses a biorisk challenge during global crises[65],[66]. Scientifically sound information campaigns and vaccine distribution strategies are essential to combat vaccine hesitancy and achieve herd immunity against infectious diseases.

Capacity Building: Building local capacity for disease detection and response is crucial, especially in regions where emerging infectious diseases are more likely to occur. This includes training healthcare workers, veterinarians, and researchers in biorisk management and disease surveillance.

One Health Approach: The One Health approach recognizes the interconnectedness of human, animal, and environmental health aspects in the evolution and spread of SARS Cov-2. The One Health approach promotes collaborative efforts between different sectors to address the complex challenges posed by naturally occurring diseases[67],[68],[69] For example, global warming can lead to habitat loss and alterations in ecosystems, driving changes in the distribution of wildlife species. This ecological disruption can facilitate the spillover of zoonotic diseases from wildlife to humans, as seen with diseases like Ebola and COVID-19[70],[71]. The security dimension of the One Health approach also requires attention[72]. Biorisk management strategies must address the risks of zoonotic diseases and the underlying environmental factors.

6. Good biorisk management during global crisis

The outbreak of the COVID-19 pandemic brought the world to a standstill and highlighted the critical importance of biosafety and biosecurity measures. The global response to the pandemic exposed various gaps and challenges that must be addressed to better prepare for future pandemics. To enhance our capacity to respond effectively to the next pandemic, we must prioritize and improve biosafety and biosecurity practices.

Laboratory Biosafety and Biosecurity

Laboratories play a crucial role in disease research and diagnostics, but they also pose potential risks when not properly managed. To enhance pandemic response, laboratory biosafety and biosecurity measures need to be strengthened:

- Standardization of Protocols: There is a pressing need for the standardization of laboratory protocols and practices across the globe. A unified set of biosafety guidelines will help ensure that research is conducted consistently and safely, reducing the risk of accidents or accidental releases of pathogens.

- Training and Certification: Laboratory personnel must undergo rigorous training and certification programs to ensure they are proficient in handling dangerous pathogens. Continuous education and skill assessment are essential components of this strategy.

- Regular Inspections and Audits: Independent organizations should conduct regular inspections and audits of laboratories to ensure compliance with biosafety and biosecurity standards. These audits should not only be reactive but also proactive, aiming to prevent potential risks.

- Enhanced Reporting: Encouraging a culture of transparency and immediate reporting of accidents or potential breaches is vital. Reporting mechanisms should be streamlined, and whistle-blower protection policies should be implemented to remove any barriers to reporting concerns.

- Advanced Technology: The use of advanced technology, such as automation, in laboratories can significantly reduce the risk of human error and improve containment. Investing in such technology is imperative for the safety of laboratory personnel and the public.

Surveillance and Monitoring

Monitoring and early detection are critical aspects of pandemic preparedness. To improve these elements, the following measures should be considered:

- Global Surveillance Networks: Establishing and strengthening global surveillance networks can help detect the emergence of new pathogens quickly. These networks should be highly collaborative, sharing information and resources to improve global preparedness.

- Real-Time Data Sharing: Timely data sharing is crucial for early detection and response. Governments, health organizations, and research institutions should commit to sharing data on emerging diseases openly. International treaties could facilitate this cooperation.

- Integration of Advanced Technologies: Leveraging artificial intelligence, machine learning, and big data analytics can help detect unusual patterns in disease spread and behavior, allowing for early intervention.

- Enhanced Veterinary Surveillance: Many pandemics originate in animals before jumping to humans. Therefore, strengthening veterinary surveillance is essential. It can help identify potential zoonotic diseases before they become human pandemics.

International Cooperation

Pandemics know no borders, and international cooperation is vital to a successful response. Here are some strategies to improve international collaboration:

- Strengthen WHO and International Treaties: The World Health Organization (WHO) should be empowered to enforce international health regulations and promote collaboration between nations. Developing international treaties that outline responsibilities in pandemic response can ensure a coordinated global effort.

- Information Sharing Agreements: Nations should establish agreements for sharing critical information and resources during a pandemic. These agreements should be legally binding to ensure compliance.

- Joint Research Initiatives: Collaborative research projects involving scientists from different countries can lead to a better understanding of pathogens and more effective countermeasures. Such initiatives should be encouraged and supported financially.

- Capacity Building in Developing Countries: Developing countries often lack the infrastructure and expertise for effective pandemic response. Assistance programs and capacity-building initiatives should be established to bridge this gap.

Public Engagement

Engaging the public is crucial for a successful pandemic response, and this can be achieved through several means:

- Education and Awareness: Governments, health organizations, and the media must work together to educate the public about the risks and precautions associated with pandemics. This should be an ongoing effort, not just during outbreaks.

- Transparency: Governments and health authorities should be transparent in their communication. Hiding information or downplaying risks can lead to distrust and panic. Honest and open communication is essential.

- Community Engagement: Local communities should be actively involved in pandemic response efforts. Engaging with community leaders and organizations can help in disseminating information, coordinating local response efforts, and ensuring compliance with public health measures.

7. Concluding recommendation - Specialist Training

Specialists trained in biosafety and biosecurity are essential for safeguarding public health and ensuring the responsible handling of biological materials.

Specialist Training in Biosafety:

Biosafety specialists play a crucial role in preventing accidental exposure to dangerous pathogens. These specialists need comprehensive training that covers risk assessment, proper laboratory practices, personal protective equipment (PPE) use, and waste disposal. During pandemics, their training must be augmented to include procedures specific to the novel pathogen.

Adequate training is essential to minimize the risk of laboratory-acquired infections and accidental release of infectious agents. Specialized biosafety courses, drills, and certifications should be mandatory, and ongoing professional development must be encouraged to keep specialists updated on the latest safety protocols.

Specialist Training in Biosecurity:

Biosecurity specialists focus on preventing the theft, loss, or deliberate misuse of biological materials, especially those with pandemic potential. During pandemics, heightened vigilance is necessary to protect sensitive biological data and materials. Their training encompasses security measures, access controls, and incident response protocols.

Training for biosecurity specialists should incorporate pandemic-specific scenarios, emphasizing the importance of securing research facilities, monitoring personnel, and ensuring data protection. Collaboration with law enforcement and intelligence agencies becomes critical to counter potential threats.

Swiftly delivered, specialist training of biosafety and biosecurity specialists focused on the relevant new pathogen is essential to prevent the future spreading of pathogens around the world. To achieve this and to protect nations around the world from a repeat of the COVID-19 pandemic, high-income countries must support lower-income countries in providing funding and expertise for such training whilst recognizing the need for mutual learning.

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