



RESEARCH ARTICLE

ADVANCES IN BIOSAFETY AND BIOSECURITY: CHALLENGES AND FUTURE PERSPECTIVES IN INDIA AND NEPAL

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ABSTRACT

Global health security is currently a burning issue worldwide. This is primarily because the world is faced with the spread of newly emergent and re-emergence of infectious microorganism. The term Biosecurity is broadly the policies and practices that protect against the deliberate misuse of biology to cause harm. It is a comprehensive and strategic framework of measures, protocols and policies aimed at preventing, managing and reducing risks caused by harmful fatal biological agents. It covers the different parameters starting from protecting and safeguard the agricultural aspects on the other way the environment considering the human health against pandemics and bioterrorism. It covers agriculture, food safety, ecological or environmental protection, different defence mechanisms against intentional bioterrorism or the major one are accidental outbreak. Level of Biosecurity are considered as isolation of new animals in farm level as national control and border controls in international level. The major strategies of Biosecurity include physical, structural and management measures such as controlling access, equipment disinfection and also continuous monitoring of pests.

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INTRODUCTION

Biosecurity refers to the collection of strategies and preventive measures aimed to stopping the introduction, establishment or spread of harmful organisms such as viruses, bacteria, plants, animals and other biological agents. These organisms may spread either deliberately or accidentally beyond their natural habitats into new environments. In case of the agricultural sector biosecurity practices help safeguard food crops and livestock from pests, invasive species and other harmful organisms that may threaten food production and human-wellbeing. The concept of biosecurity covers biological threats that can affect human health, including the risks posed by large scale disease outbreaks and acts of bioterrorism. Over time, the meaning of biosecurity has expanded to include several related areas, and it is applied in different ways depending on the context and purpose. A recent global example highlighting the importance of biosecurity is the COVID-19 pandemic, which demonstrated the urgent need for effective biosecurity measures across countries worldwide. Even though scientists from multiple countries concluded that the virus responsible for the coronavirus pandemic shifted naturally from an animal source to a human host (Nandi, 2020). The international community should not ignore the possibility of pathogens escaping accidentally from research labs and threats of

deliberate manipulation to create more dangerous bioweapons stated by WHO (Koblentz & Gregory, 2010).

In recent decades, several harmful infectious diseases have emerged in different parts of the world, such as the Ebola virus disease in West Africa, the Zika virus disease in South America, severe acute respiratory syndrome (SARS) in China, and the Nipah virus disease in India are not only limited to the region but frequently put people all over the world at risk. Most recently, COVID-19, the disease caused by the novel corona virus, originated in China in late 2019 and rapidly evolved into a global pandemic, clearly demonstrating the harm infectious diseases can cause to the world economy and health security. Such events highlight the critical importance of biosecurity which aims to prevent, detect and respond to biological threats in order to protect human health, economic stability overall the global security as well.

Worldwide different Biological Threats: Biological threats have emerged as a major concern for global society. Different natural biological processes such as mutation, evolution and transmission can give rise different infectious diseases that threatened human health and also not concern the geographical boundaries. In addition to natural causes, human activities may also create biological risks either unfortunately or deliberately. The term "laboratory biosecurity," first advanced

by the World Health Organization in 2006, encompasses the “protection, control, and accountability for valuable biological materials within laboratories.” Several incidents have demonstrated how laboratory accidents can lead to the spread of infectious agents worldwide. In 2003 when a Singaporean researcher acquired SARS from inadvertent cross-contamination of viral samples (World Health Organization, September 24, 2003). Similarly In 2004, the accidental release of the SARS virus from a Chinese laboratory infected nine people, one of whom died (Parry, 2004). In 2014, a researcher working in a lab in India was accidentally infected with buffalopox virus (Riyesh *et al.*, 2014). In 2019 more than 3,000 brucellosis cases were detected in China due to contaminated exhaust from a brucellosis vaccine-making company (Indian Express, 2020). Going further back in history, during World War II, Japan deliberately used pathogens to spread plague, anthrax, typhoid, cholera, and other diseases among Chinese military and civilians (Guillemin, 2006). The United States and the Soviet Union developed major biological weapons programs during the Cold War (Guillemin, 2006). part of the Soviet Union, continued illegally even after it signed the Biological Weapons Convention in 1972 (Rissanen, 2003).

Despite these potential dangers, bioscience and biotechnology offer significant benefits to humanity. Research in genomics enables scientists to understand the genetic causes of diseases affecting humans, animals and also plants. Furthermore, advances in synthetic biology and gene editing technologies provide powerful tools for modifying genes to treat diseases and develop new biological functions. These scientific developments play a crucial role in the development of vaccines against infectious diseases like COVID-19 and in creation of medicines for individuals who cannot be vaccinated. In addition, modern biotechnological innovations contribute to improved disease prevention, enhance medical treatment, increased agricultural productivity and sustainable development. Therefore, strengthening biosecurity measures is essential to ensure that biological research and technological progress are used safely and responsibly for the benefit of society. There have been detected five pillars of biosecurity like inventory process, physical security, personal reliability program, transport programs, and information security processes as well.

Role of Education: Education plays a vital role in strengthening biosecurity by creating awareness, developing scientific knowledge in the field of life science and biotechnology as well as promoting responsible behaviour in handling biological materials. Bio security refers to the measures taken to prevent the misuse, accidental outbreak or rapid spread of different biological agents that has detrimental effects on human health, agriculture and in the environment. Firstly, the education helps in raising the awareness about different biological risks and safety practices. With the help of proper knowledge among the students, researchers and the professionals learn that how the biological agents can spread and the process of minimize its risks. Secondly, education develops scientific skills and the knowledge which are necessary for the safe laboratory practice and research aspects. Thirdly, education promotes the responsible researches and also the ethical conduct in scientific researches. It ensures that these technologies will always be used for the beneficial and novel purposes like vaccination, control of disease transmission, reduce the outbreak of pandemic but not for the harmful activities. In this way education take the major role in

building the strong security systems. It not only prepares the skilled professionals but also protects the environment from any kind of biological threats. However, one way of ensuring that the life sciences continue to generate significant benefits which is not become the subject to misuse for hostile purposes. It is a process of engagement between scientists and the security community, which helps to develop the strong ethical and normative frameworks to complement legal and regulatory measures that are developed by states (Novossiolova & Tatyana, 2016 and Simon *et al.*, 2020).

Status of Biosecurity in Nepal: Nepal has been taking several initiatives to enhance food safety and improve the quality of food products. The country is also working to control diseases and pests, regulate the use of chemical pesticides, ensure the quality of medicines including veterinary drugs, strength quarantine systems, and also manage genetically modified organisms. To support these activities the Government has introduced nearly a dozen policies, more than two dozen legal acts, and about eight different departments are directly or indirectly involved in implementing them. However, the efforts are found scattered with many gaps and overlaps. In the meantime, the country suffers from health risks emanating from food products, leading to public health problems, limited ability to meet sanitary and phytosanitary requirements for agricultural exports, and increased food import dependency, notably in the high-income segments which includes the tourism sector. Furthermore, these challenges weaken the connection between small holder farmers and high-income food markets, ultimately affecting their income opportunities and threatening their livelihoods. Considering the biosecurity in different areas of Nepal it is observed that existing policies, legislations, and institutional mechanisms related to biosecurity are fragmented and not sufficiently effective in reducing the risks proposed by various natural and anthropogenic hazards across different stages of the agro food supply chain. Natural hazards mainly include diseases and pest infestations affecting crops, forests, livestock, poultry and fisheries, many of which are also transmitted to the human beings. Examples of naturally occurring biosecurity risks include toxic mushrooms, wild honey contamination and the presence of mycotoxins in food and animal feed. In contrast the anthropogenic hazards often cause greater threats. These includes excessive residues of pesticides and veterinary drugs in food products, the use of ripening agents, artificial colouring substances, food adulterants, preservatives and the contamination through polluted water sources. Implementing biosecurity measures can increase production costs.

Considering the harmful effects of Bioterrorism in worldwide and also the economic upliftment of the country policy makers proposed several recommendations for the betterment of the country and economic upliftment as well as for the protection of human health and overall environment. Nepal has no choice but to work hard towards for bio secure agriculture. The proposed recommendations by different scientists for the betterment of human beings as well as for the country economy are like inclusion of labelling and traceability systems, which can promote market based agricultural development model. Motivation and encouragement to the farmers to adopt the safe practices focusing the infrastructure and modern essential technologies. Some recommendations also suggested regarding development of institutional laws and policies in addition to research identifies new and existing hazards and also their possible impacts. Emergency planning

which is urgently required to manage biosecurity risks. Coordination among different agencies is urgently required for effective action. Continuous monitoring on food borne diseases, testing food samples in the laboratories in addition to early detection and prevention strategies are essential. Technological supports are also essential at the initial stage where farmers also be very much aware about the quality control support, and the large-scale producers and the companies must be implementing the biosecurity measures but essentially need certification and liability rules. Cultivators should be trained about safe production methods and proper harvesting techniques. In addition to proper packaging, clean water, cold storage and suitable transportation is also essential. On the other hand, consumers also be aware about safe storage, method of cooking and food labels. Over the all-Government support system including subsidies can promote these measures. Considering the fatal and pandemic effects of different bioagents emergency planning is urgently needed to manage biosecurity risks in world wide.

Biosecurity status in India: India is especially vulnerable to various types of infections because of its large population, geographical position, low healthcare spending, reduced expenditure on research that benefits public health, poor coordination between central and state health authorities, limited involvement of private actors and NGOs, poor awareness of biosecurity, and the rickety state of public health infrastructure. Most recently, the devastating affects of COVID-19 has revealed the shortfalls of India's public health infrastructure, including a shortage of healthcare workers, lack of trained epidemiologists, scarcity of medical equipment, poor access to healthcare facilities in rural areas, and inefficient disease reporting and surveillance in most states. The pandemic must act as a wake-up call for India to examine the gaps in its public health infrastructure and redirect resources towards strengthening the health care system to handle both natural and man-made biological emergencies.

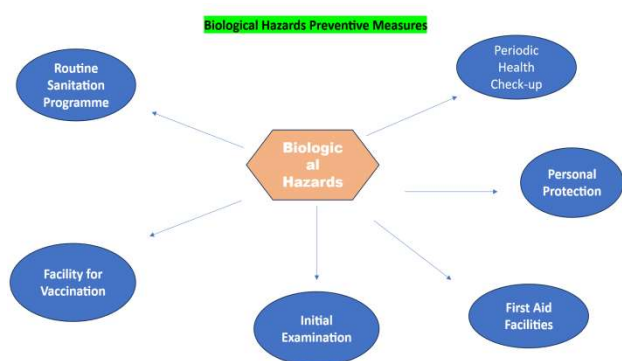


Fig. 1. Suggestive Proposals to control Biological Hazards followed by India

Although India has multiple authorities set up at each step to ensure safety of biotechnological research, experts in India point out that illegal cultivation of genetically modified cotton and brinjal in different pockets of the country exposes the weak implementation of biosafety guidelines and limited communication with the society (Vishwa Mohan, 2019).

Safety and Security Regulations and Policies in India: To address safety and security risks, India follows two different approaches in biosafety and biosecurity. In Biosafety seeks to protect humans from pathogens while biosecurity protects

pathogens from humans. In India there are four major Biosecurity measures have been detected, like i) Intentional

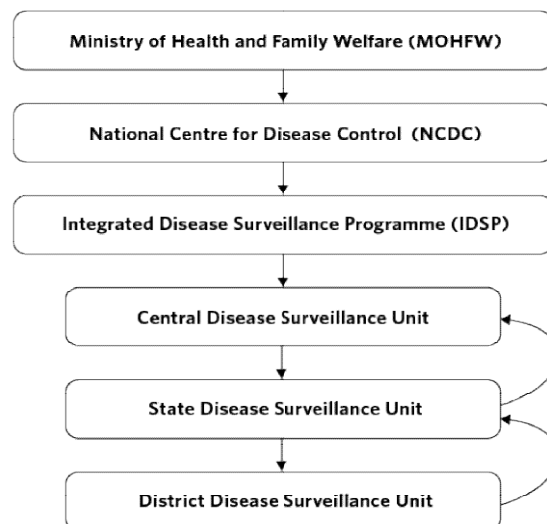


Fig. 2. Disease Surveillance Model in India (Source Google)

release of invasive pests or pathogens to disrupt India's agricultural supply chain, ii) Deliberate introduction of naturally occurring infectious disease-causing organisms, such as anthrax or coronavirus, by nefarious actors or hostile states to cause human infections, iii) Synthetic creation of dangerous organisms from scratch, either by using genomic information available online or acquiring information through unauthorized means for non-legitimate use and iv) Vulnerability to cross-border infections. Different experts have highlighted that no restrictions exist for plants or other organisms modified through traditional techniques in India. They added that traditional biotechnology techniques such as selective breeding, hybridization, and fermentation have been used to modify living plants for improved yield or enhanced nutritional value. In addition to producing the desired product, these traditional breeding techniques can lead to random mutations. This practices have great chance to reduce the accidental outbreak of biotechnological techniques and have less risk. However the Indian government adopted a multilayered regulatory system to examine the safety of biotechnology products before their commercialization. India tackled different bioterrorism in near past against Kyasanur Forest Disease in 1957, high-density poultry population combined with the illegal movement of poultry and poultry products makes India vulnerable to avian influenza, in 2005 to 2015. These out breaks India protects the resources very carefully by imposed some restrictions and regulations. India has a comprehensive set of biosafety guidelines that have been issued by the Department of Biotechnology, Different implementations of biosafety guidelines falls under the ambit of the Ministry of Science and Technology and MOEFCC, researchers often work in labs supported by the ICMR and the Indian Council of Agricultural Research, which are research bodies set up under the MOHFW and the Ministry of Agriculture and Farmers' Welfare. But these regulations are always not so transparent.

Future: Considering the future of Biosecurity, it is essential to cooperate among the scientists, technicians, policy makers, security engineers, and law enforcement officials. (Kelsey, 2022 and Salerno, 2007).The nature of modern biosecurity threats is changing in war footing, even the small risks can also

develop very rapidly. Due to limited time and resources for analysing these threats and predicting their likelihood, developing effective biosecurity policies become more difficult. In the upcoming future stronger collaboration with other scientific disciplines such as virology and chemical contaminant detection will be necessary to better understand and manage these unforeseen risks. There are still many uncertainties regarding the implementation of the policies of biosecurity. Policy makers must estimate potential risks factors and the different predictions of different threats in order to design the different strategies for preventiveness. However, the unpredictable and complex nature of biosecurity makes accurate prediction very challenging. Addressing one immediate threat may sometimes invites another unpredictable risk in the future. Philosopher Toby Ord, in the book “The precipice: Existential Risk and the Future of Humanity (2020, 2021), questioned whether current international regulations and self-regulation by biotechnology companies and scientific communities are sufficient to control the risks associated with biotechnology research and development.

To reduce risks from life science research, scientists have suggested several policy-based measures. These include establishing new international guidelines, improving regulatory oversight, strengthening national policies so that they can influence global standards and identifying gaps in existing biosecurity framework (*Science Media Center Germany*, 2022), (Jaspreet *et al.*, 2022). Recently researches have also warned about the possible risks of “Mirror life” – theoretical form of life whose molecular structure has reversed chirality. If mirror bacteria were ever created, they might escape natural immune responses and spread in the environment without natural predators (Adamala *et al.* 2024). Although technology to produce such organisms is still likely many years away, scientists have already recommended strict restrictions on research aimed at creating them.

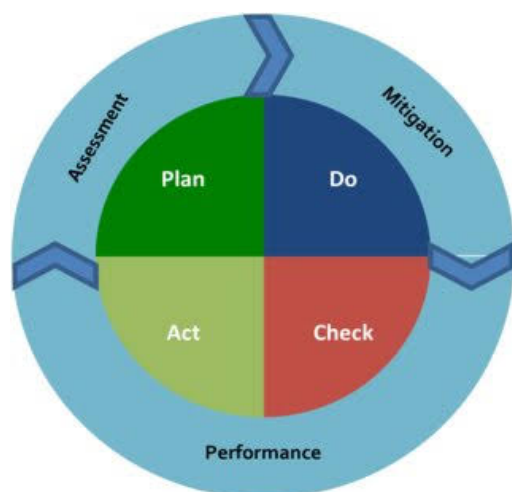


Fig. 4. Major Recommendations for the improvement of Biosecurity in the Developing Countries (Source Google)

The increasing emergence and spread of infectious diseases represent a persistent and evolving challenge to public health as well as national security. Strengthening biosecurity has therefore become an essential priority for different countries having high population. Establishing a dedicated institutional framework for the prevention and management of biological threats could significantly improve national preparedness and also response capacity (Shruti, 2020). In this context, the

creation of an Office of Biological Threats Preparedness and Response (BTPR) under the National Disaster Management Authority (NDMA) may serve as an effective coordinating mechanism. This office could focus on naturally occurring diseases, threats emerging from laboratory accidents, and deliberate weaponization of diseases. In addition, to improve the national biosecurity requires improved coordination among Government agencies, the private sectors and the scientific community. Regular review or supervision of domestic preparedness systems along with capacity building measures such as periodic training of healthcare workers in safe medical practices and proper handling of biological samples is essential for effective prevention and response to biological threats. The different measures to respond both natural and man-made biological threats include:

- Capacity Building and Training of Healthcare Personnel regarding safe handling of samples, decontamination procedures, and proper disposal of biomedical waste
- Enhancing Coordination Between Central and State Health Systems.
- Promoting Effective Disease Detection and Reporting Mechanisms.
- Integrated data sharing for Early Outbreak Detection from different disease surveillance programs that collect data on plant, animal, and human health to detect outbreaks in a timely manner.
- Standardizing Disease Reporting Frameworks from all organizations reporting disease outbreaks.
- Building a collaborative Epidemiological Model for collaboration between government, scientists, academicians, industry, epidemiologists, and data scientists
- Strengthening Public Health Capacity and Infrastructure such as funding to research bodies, investment in biotechnological research and promote collaboration between the scientific and the policy makers.
- Regulatory Oversight of Biotechnological Research
- Unifying Application & Evaluation Processes for Biotechnology Approvals
- Essential certification and proper validation of the laboratories using high risk pathogens.
- Comprehensive Biosecurity Policy Integrating Plant, Animal and Public Health Threats to Prevent Sector Overlaps.
- Specialized Training for Customs Officials on Identifying Security-risk Pests or Pathogens.

Biosecurity – A Global Concern: Over the years the concept of biosecurity has been largely adopted by a number of countries like India and other parts of Asia. Since 2007, biosecurity has been included as a key element in the European Union Animal Health Strategy. Different countries all over the world developed various strategies to overcome these detrimental effects of different bioagents by focusing continuous monitoring on food borne diseases, testing food samples in the laboratories in addition to early detection and prevention strategies, risk analysis system and establishment of quarantine, food quality and pesticide control in imports. It is also essential in national decisions about the use of pesticides, hormones, antibiotic and veterinary drugs. It ensures safety measure in food production, food processing, control of contamination and additives as well. Different awareness campaigning among the farmers and other agro food suppliers is very much essential at initial stages. On the other hand,

consumers also be aware about safe storage, method of cooking and food labels. In addition to technological supports are also essential at the initial stage. Not only that the large-scale producers and the companies must be implementing the biosecurity measures essentially by certification and liability rules. The Global Health Security Index in 2019 assessed the global health security capacities of 195 countries using open-source data. Different countries like Germany, Singapore, Sweden, United States, Denmark, Norway etc. have mandated and standardised training to reduce risks from deliberate misuse of dangerous pathogens. But still there is a marked absence of regulations concerning biosafety and biosecurity around the world. Regulatory Oversight of Biotechnological Research is very essential in every parameter of security, essential certification and proper validation of the laboratories using high risk pathogens is mandatory, integrated data sharing for early outbreak detection from different disease surveillance programs are very essential for every country. The most important thing is that for every country a collaborative epidemiological model for the collaboration between government, scientists, academicians, industry, epidemiologists, and data scientists is essential to overcome this alarming situation. By taking collective action today we can build a safer and more secure world for generations to come. In addition, to improve the national biosecurity requires improved coordination among Government agencies, the private sectors and the scientific community. Regular review or supervision of domestic preparedness systems along with capacity building measures such as periodic training of healthcare workers in safe medical practices and proper handling of biological samples is essential for effective prevention and response to biological threats as well as to escape this dreadful situation universally.

CONCLUSION

In conclusion we can say that, biosecurity is not only a scientific and medical concern but also a global responsibility. In the near history different countries faces different challenges in both natural and man-made pandemic situations. So, a coordinated and pro-active approach is necessary from the grassroot level to the highest hierarchal level to combat and protect the human health, the biological resources and overall, the environment and ecosystem. By taking collective action today we can build a safer and more secure world for generations to come.

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