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ENSURING BIOLOGICAL SAFETY AND BIOSECURITY IN HANDLING PATHOGENIC MICROORGANISMS AT THE RESEARCH INSTITUTE OF BIOSAFETY AND BIOSECURITY

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Abstract. This article summarizes the experience of the Research Institute for Biological Safety Problems (RIBSP) in ensuring biological safety and biosecurity when handling pathogens of especially dangerous and exotic animal diseases, including zoonotic diseases. All aspects of the facility's safe operation are critically analyzed, including engineering, technical, and technological support, personnel training requirements, protocols for handling highly dangerous pathogens, specific preventive measures, and the regulatory framework. The article highlights the RIBSP's compliance with modern BS and biosecurity standards, which ensures the facility's sustainability in these areas.

Keywords: biological safety; biosecurity; pathogenic microorganisms; personnel; biological risk.

Introduction

The study of pathogenic biological agents (PBA) is inherently associated with the risk of laboratory accidents, which can lead to infection of personnel and the potential release of pathogens outside the laboratory [1-5]. Throughout the history of microbiological and virological research, cases of laboratory-acquired infections have been recorded, highlighting the occupational hazards and professional risks associated with such work [4, 5]. From 2000 to 2021, there were 16 documented instances of pathogenic microorganism leaks from laboratories, 37.5% involving bacteria and 62.5% involving viruses. One of the largest incidents occurred in 2019 when an outbreak of brucellosis affected 10 528 individuals due to a leak at a pharmaceutical plant in Lanzhou, China [6]. Such incidents are generally attributed to breaches in biosafety protocols or insufficient oversight by biosafety services in laboratories and related institutions [6].

According to the World Health Organization (WHO), more than 200 zoonotic diseases are known, and it is estimated that 60% of all human infectious diseases are zoonotic in origin. Moreover, 75% of emerging infectious diseases in humans are of animal origin, and 80% of pathogens with potential bioterrorism applications are zoonotic [7]. The cultivation of microorganisms for research, vaccine development, and diagnostic purposes carries inherent risks of environmental contamination. Activities such as handling pathological materials, preparing virus-containing suspensions, and analyzing biological samples also present significant biosafety challenges [1, 4, 6].

The issues of biosafety and biosecurity for laboratory personnel and the environment have become increasingly urgent with advancements in microbiology, genetic engineering, and the expansion of the microbiological industry. This urgency is further heightened by the potential for

the use of biological agents in acts of terrorism [1, 4, 8]. In this context, the potential consequences of both accidental and intentional releases of microorganisms into the environment must be carefully considered, along with preparedness for managing such events [5, 9]. Therefore, the primary principle for ensuring the safe operation of laboratories handling pathogenic microorganisms is the establishment of biosafety and biosecurity measures that are proportional to the biological risks. It is essential to fully understand the risks involved in working with microorganisms, recognize the mechanisms that can lead to hazardous situations, employ safe work practices, and remain vigilant against potential errors [3, 4, 5, 9, 10].

The purpose of this study is to assess the biological risks associated with working with pathogenic microorganisms, evaluate the compliance of existing engineering and technical systems with biosafety and biosecurity requirements, and analyze the current training programs for personnel handling especially dangerous pathogens. The study also aims to review the regulatory framework that governs the safe operation of research institutes.

Materials and Methods

This study utilized comparative analysis to evaluate existing engineering and technical systems for compliance with biosafety and biosecurity requirements. We also assessed the protocols followed by personnel working with especially dangerous pathogens. The organizational measures examined included the coordination of safety systems, the regulation of procedures, and the rules for handling pathogenic microorganisms.

We monitored the functionality and effectiveness of biosecurity systems and observed personnel adherence to safety protocols. In evaluating the functioning of the facility, we placed particular emphasis on the timely implementation of measures to maintain sanitary conditions (e.g., disposal of biological waste, disinfection, deratization, and sanitation of premises) in accordance with the applicable norms and regulations of the Republic of Kazakhstan. The handling, accounting, storage, and transportation of pathogenic microorganisms in the laboratories of the Research Institute for Biological safety problems (RIBSP) were compared with the requirements of the relevant sanitary and veterinary guidelines approved in Kazakhstan. We also assessed the medical care and periodic health examinations provided to employees involved in these experiments.

Research Results and Discussion

The handling, registration, storage, and transportation of microorganisms at the RIBSP are regulated by the following legal documents:

- Order of the Minister of Healthcare of the Republic of Kazakhstan No. ҚР ДСМ-125 dated November 2, 2022, “On the Approval of Rules for Ensuring Biological Protection”;
- Law of the Republic of Kazakhstan No. 122-VII ЗРК dated May 21, 2022, “On Biological Safety of the Republic of Kazakhstan”.

The establishment of the institute was driven by the necessity to develop methods for protecting the southern borders of the USSR, the republics of Central Asia, and Kazakhstan from highly dangerous, especially exotic, infectious diseases affecting agricultural animals and plants that could be brought from neighboring countries.

Following Kazakhstan's independence, the RIBSP was one of the first in the country to tackle the challenges of biological safety [11]. In line with its research agenda and international programs, the institute conducts virological, microbiological, molecular genetic, biochemical, and immunological studies on microorganisms from pathogenicity groups II-IV, including pathogens of

particularly dangerous infectious diseases affecting animals and birds. The institute also investigates museum, natural, and vaccine strains, determining their virulence and immunogenicity through experiments on model laboratory animals and naturally susceptible species [12].

In compliance with sanitary regulations, the institute's laboratories are divided into three zones according to the level of danger to personnel: "infectious", "conditionally infectious" and "clean". For handling pathogenic biological agents, the institute is equipped with BSL-2 and BSL-3 laboratories. To ensure personnel safety and prevent the release of dangerous pathogens into the environment, engineering provisions for biological safety were implemented from the initial design phase of the laboratory buildings. This includes a robust filtration and ventilation system, zoning of containment areas, a wastewater disinfection system, and local sanitary checkpoints for employees.

Modern methods for studying dangerous and highly dangerous pathogens are supported by a comprehensive biosafety and biosecurity system. These systems aim to mitigate the risk of infection and prevent the release of microorganisms beyond laboratory or institute boundaries. Biosecurity is enhanced by an integrated access control system, and laboratories are equipped with containment boxes, antechambers, workrooms, and auxiliary rooms for preparing glassware and solutions. The institute also has an exhaust and supply ventilation system with HEPA filters, as well as a sewage system with local reservoirs that prevent uncontrolled releases of pathogens. Wastewater and liquid waste undergo a three-stage chemical disinfection process. All work with experimental animals is conducted in specialized vivariums (isolators).

The safety of operations involving microorganisms at the RIBSP is ensured through a variety of measures, including:

- Territorial restrictions;
- Categorization of laboratory work areas;
- Sealing of laboratory enclosures;
- Maintenance of appropriate air exchange rates and airflow direction in laboratories;
- Use of biological safety cabinets, laminar flow hoods, and containment rooms;
- Disinfection of liquid and solid biowaste;
- Ensuring the proper functioning of life-support systems [1, 5, 9, 12].

According to the "Law on Biological Safety of the Republic of Kazakhstan", working safely with pathogenic microorganisms requires specialized training and extensive experience for personnel. This is a critical condition for ensuring both biosafety and biosecurity when handling especially dangerous infections. One of the primary goals is to develop practical skills for safe handling of pathogens and ensure compliance with biosecurity protocols at facilities where highly dangerous biological agents are managed. Furthermore, preventing the unauthorized movement and removal of pathogens from these facilities is a key objective [5, 9].

In the RIBSP, training programs, seminars, professional education, re-training, and advanced training in biological safety are conducted by certified specialists and organizations accredited according to the legislation of the Republic of Kazakhstan. Within the framework of international projects, the Defense Threat Reduction Agency (DTRA) organizes training sessions on biosafety and biosecurity, emergency response during research in BSL-3 conditions, and laboratory skills required for working in BSL-3 laboratories. Additionally, mentoring is highly valued at the RIBSP, where senior scientists—who have safely worked with pathogenic materials—enthusiastically share their invaluable experience and knowledge with the younger generation of specialists. This mentoring significantly contributes to compliance with biosafety and biosecurity requirements when working with pathogens.

An analysis of the scientific work conducted at the RIBSP shows that adhering to biosafety protocols and conducting biological risk assessments simplifies the identification of root causes of incidents, thus preventing their recurrence. Training programs provided to staff have helped assess their competence in handling dangerous pathogens. The institute's medical and sanitary control system also plays a key role in assessing risks for personnel engaged in different types of scientific and industrial activities, identifying suitable personal protective equipment (PPE), and planning the procurement of immunoprophylactic drugs [13].

Three key aspects contribute to ensuring work safety: organizational and control measures, engineering and technical solutions, and medical-biological measures. These aspects are interrelated and interdependent. A comprehensive approach to the development and implementation of clearly regulated procedures is crucial for addressing these safety challenges effectively [14].

To enhance the importance of biosafety and biosecurity in research on pathogenic biological agents, new regulatory documents and standard operating procedures (SOPs) are continuously updated and developed across laboratories and departments. Regular audits of laboratories are conducted to ensure compliance with biosafety and biosecurity standards.

The RIBSP is equipped with a modern laboratory and technical infrastructure, including BSL-2 and BSL-3 facilities that fully comply with WHO requirements for working with dangerous human and animal pathogens. Engineering, technical, and medical-biological measures, when adequately funded, ensure the safety of both personnel and the environment by maintaining engineering systems in optimal working condition, as well as carrying out timely routine and preventive repairs. These measures also include biosafety protocols for working with laboratory and farm animals, conducting bioassays, and studying particularly dangerous infections circulating in Kazakhstan. Moreover, they are critical in responding to the emergence of new exotic viral diseases, which is especially relevant today. The standard protocol for assessing biological risks in laboratories and isolation wards for experimental animals is currently being refined. This protocol helps assess the risk of personnel infection, taking into account the laboratory's equipment, engineering, and technical characteristics, as well as the qualifications of staff. It also factors in the characteristics of the pathogen and the risks of uncontrolled spread. The protocol is designed to identify biological risks and outline measures to reduce or eliminate them effectively.

Conclusion

The measures implemented at the institute ensure a high level of biosafety and biosecurity, protecting laboratory personnel and preventing the release of pathogenic biological agents from the RIBSP. Today, the institute stands as a leading scientific institution in Kazakhstan in the fields of veterinary and medical virology, genetic engineering, and biotechnology. The team of scientists at the institute generates innovative scientific ideas, develops new biotechnologies, and manages the production of vaccines and other biopreparations. As a small biotechnological cluster, the institute is capable of independently addressing biosafety challenges posed by dangerous pathogens [15].

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БИОЛОГИЧЕСКАЯ БЕЗОПАСНОСТЬ И БИОЗАЩИТА ПРИ РАБОТЕ С ПАТОГЕННЫМИ МИКРООРГАНИЗМАМИ В НИИПББ

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Аннотация. В статье представлены материалы, обобщающие опыт работы Научно – исследовательском институте проблем биологической безопасности (НИИПББ) по

обеспечению биологической безопасности (ББ) и биозащиты (БЗ) при работе с возбудителями особо опасных и экзотических болезней животных, включая антропозоонозы. Критически проанализированы все аспекты безопасного функционирования объекта - инженерно-техническое и технологическое обеспечение, требования к подготовке персонала и проведения работ с возбудителями особо опасных болезней, специфической профилактике и нормативно-правовой базе. Отмечено соответствие НИИПББ современным требованиям ББ и БЗ, что позволяет обеспечивать устойчивость объекта в данных областях.

Ключевые слова: биологическая безопасность; биозащита; патогенные микроорганизмы; персонал; биологический риск.

БҚПҒЗИ ПАТОГЕНДІ МИКРООРГАНИЗМДЕРМЕН ЖҰМЫС ІСТЕУ КЕЗІНДЕГІ БИОЛОГИЯЛЫҚ ҚАУІПСІЗДІК ЖӘНЕ БИОҚОРҒАНЫС

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Аннотация. Мақалада жануарлардың аса қауіпті және экзотикалық ауруларының қоздырғыштарымен, сонымен қатар антропозооноздармен жұмыс істеу кезінде биологиялық қауіпсіздікті (БҚ) және биоқорғанысты (БҚ) қамтамасыз етудегі Биологиялық қауіпсіздік проблемаларының ғылыми-зерттеу институтының (БҚПҒЗИ) тәжірибесін айқындайтын материалдар ұсынылған. Объектіні қауіпсіз пайдаланудың барлық аспектілері – инженерлік-техникалық және технологиялық қамтамасыз ету, персоналды оқытуға және аса қауіпті аурулардың қоздырғыштарымен жұмыс істеуге қойылатын талаптар, спецификалық алдын алу және нормативтік-құқықтық база салыстырмалы тұрғыдан талданды. БҚПҒЗИ биологиялық қауіпсіздік және биоқорғаныста заманауи талаптарға сәйкес келетіні атап өтілді, бұл осы тұрғыда объектінің тұрақтылығын қамтамасыз етуге мүмкіндік береді.

Түйін сөздер: биологиялық қауіпсіздік; биоқорғаныс; патогенді микроорганизмдер; персонал; биологиялық қауіп.