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The Biosafety Level 3 (BSL-3) Laboratory Readiness for Emerging Pathogens: A Review Study

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Abstract

Background: Emerging pathogens such as SARS-CoV-2 and drug-resistant *Mycobacterium tuberculosis* are international health concerns because of their high virulence, transmissibility, and aerosol-transmissibility. Biosafety Level 3 (BSL-3) laboratories provide necessary containment for the study of these Risk Group 3 (RG3) agents while balancing research needs with stringent safety precautions. **Aim:** This review evaluates BSL-3 laboratory preparedness for new pathogens in infrastructure, operational practices, training, and challenges to inform future outbreak responses. **Methods:** There was a systematic review of the literature, complemented by global guidelines from the CDC and WHO. Incident analyses and case studies provide valuable lessons. **Results:** Negative pressure, HEPA filtration, and rigorous training are required for BSL-3 labs to deal with pathogens like the Nipah virus and Francisella tularensis. Challenges include higher costs, disruption of the supply chain in LMICs, and risk of laboratory-acquired infection. AI surveillance and modular laboratory design help with better preparedness. **Conclusion:** BSL-3 laboratories have a pivotal role in diagnosis, vaccine development, and control of outbreaks, necessitating global investment in facilities and training to address new threats.

Keywords: BSL-3, emerging pathogens, biosafety, aerosol transmission, laboratory preparedness.

1. Introduction

The path of human history has always been shaped by infectious diseases, from the ghastly Black Death of the 14th century to the deadly 1918 flu pandemic and the recent global turmoil created by the COVID-19 pandemic due to SARS-CoV-2. Emerging pathogens, which are infectious agents newly appearing in populations or with increased incidence or geographic range, pose significant challenges due to their unpredictable patterns of transmission, high virulence, and aerosol transmissibility (Jones et al., 2008). These agents tend to be zoonotic, their emergence prompted by anthropogenic factors such as deforestation, urbanization, expanded agriculture, and increased global interconnectivity through travel and trade (Wolfe et al., 2007). Containment of such sophisticated agents necessitates special containment units, specifically Biosafety Level 3 (BSL-3) laboratories that possess the ability to confine pathogens with the potential to cause severe or even lethal diseases through respiratory exposure (Centers for Disease Control and Prevention [CDC], 2020).

BSL-3 laboratories are equipped to work with Risk Group 3 (RG3) agents—foreign or domestic pathogens posing significant risks of aerosol transmission, against which treatments or vaccines may exist but are ineffective or unavailable universally (Chosewood & Wilson, 2009). In contrast to BSL-1 laboratories, which handle non-pathogenic agents, or BSL-2 facilities, which have moderate-risk agents, BSL-3 laboratories have advanced engineering controls, including negative pressure ventilation, HEPA filtration, and mandatory respiratory protection (World Health Organization [WHO], 2020). The global growth of BSL-3 laboratories, particularly following the 2001 anthrax attacks and heightened bioterrorism concerns, has immensely enhanced biodefense capability (Aspland et al., 2021). However, this expansion is accompanied by challenges like the need for strong oversight, risk management, and prevention of laboratory-acquired infection (LAIs) (Yeh et al., 2021).

This review evaluates the readiness of BSL-3 laboratories to handle new pathogens, including viral agents (e.g., SARS-CoV-2, Nipah virus) and bacterial pathogens (e.g., *Francisella tularensis*, *Yersinia pestis*). It weaves together new guidelines, facility design requirements, operational practices, training frameworks, and concerns. The study is anticipated to provide actionable suggestions to policymakers, scholars, and biosafety professionals to optimize BSL-3 infrastructure to ensure readiness for any emerging

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outbreaks, which will prevent millions of deaths through early interventions (Aljehani & Alhayek 2024). By integrating historical data, current technical advances, and case studies, the review argues the necessity of adaptive, resilient strategies to counter the evolving threat of emergent pathogens.

Background on Biosafety Levels and Emerging Pathogens

Evolution of Biosafety Levels

The concept of biosafety level (BSL) was developed in the 1970s through concerted efforts by the National Institutes of Health (NIH) and the CDC to formalize containment protocols for recombinant DNA research as a response to fears of genetic manipulation risks (Richmond, 2013). The Biosafety in Microbiological and Biomedical Laboratories (BMBL), sixth edition, categorizes the containment into four levels depending on the risk groups (RGs) of the pathogens, from RG1 (non-pathogenic for normal adult humans) to RG4 (highly pathogenic with no known treatments) (CDC, 2020). BSL-3 labs are traditionally designed for RG3 agents, which are serious or even lethal diseases and can be spread by inhalation, creating a requirement for balancing allowing necessary research with offering good protection against aerosolized transmission (Dickmann et al., 2015).

Global BSL-3 capabilities were dramatically altered following the anthrax attack in the United States in 2001, which revealed potential vulnerabilities to bioterrorism. This resulted in a spectacular expansion of BSL-3 labs, increasing from approximately 400 in 2001 to over 1,400 through 2012, driven mostly by biodefense funding by the National Institute of Allergy and Infectious Diseases (NIAID) and other organizations (Aspland et al., 2021). Around the world, the WHO's Laboratory Biosafety Manual (4th ed) encourages the risk-based strategy, emphasizing individually tailored containment methods for new threats, particularly for regions with high disease burdens (WHO, 2020). In low- and middle-income countries (LMICs), the uptake of BSL-3 facilities remains constrained by costs—$5-10 million to build and 10-15% annually to maintain—although necessary to handle endemic infections like tuberculosis and new zoonotic risks (Kouriba et al., 2018; Alsharari et al., 2024).

Features of Emerging Pathogens

Emerging disease-causing pathogens are evolving, typically from animal reservoirs through zoonotic spillover events facilitated by ecological disruptions in terms of habitat loss and climate change (Wolfe et al., 2007). Viral pathogens like SARS-CoV-2, belonging to the RG3 group and requiring BSL-3 containment, have high transmissibility (basic reproduction number, R0, of 2-3) and asymptomatic transmission capability, complicating containment (Beshbishy, 2024). Bacterial pathogens such as *Yersinia pestis* (plague), with their low infectious doses (10-50 organisms) and highly disease-capable states, demand BSL-3 containment for aerosol-generating procedures (CDC, 2020). Other RG3 pathogens, such as *Mycobacterium tuberculosis* and *Francisella tularensis,* pose further issues in the form of antibiotic resistance and bioweapon potentiality, respectively (Dheda et al., 2017; CDC, 2020).

Climate change has the effect of accelerating the onset of vector-borne disease agents, such as West Nile virus, by expanding the range of geographical distribution of vector mosquitoes like Culex species under rising temperature and altered precipitation patterns (Kilpatrick et al., 2008). Secondly, rising levels of multidrug-resistant bacteria, such as extensively drug-resistant tuberculosis (XDR-TB), emphasize the need for sophisticated containment in order to study mechanisms of resistance and develop novel therapeutics (Dheda et al., 2017). Table 1 below shows a more detailed comparison of biosafety level

Table 1: Comparison of Biosafety Levels for Containment of Pathogens

Biosafety Level	Risk Group Agents	Primary Barriers (PPE/Equipment)	Secondary Barriers (Facility Design)	Example Pathogens
BSL-1	RG1 (non-pathogenic)	Lab coat, gloves, eye protection; open bench work	Basic access control; standard ventilation	*Escherichia coli* (non-pathogenic strains)
BSL-2	RG2 (moderate hazard)	As a BSL-1 + Class II biological safety cabinet (BSC) for aerosols, restricted access	Self-closing doors; handwashing sinks; autoclave availability	Human immunodeficiency virus (HIV), *Salmonella* spp.
BSL-3	RG3 (serious aerosol risk)	As BSL-2 + respirators (N95 or powered air-purifying respirators [PAPR]); double gloves; fluid-resistant gowns	Negative pressure (2.5-10 Pa); HEPA-filtered exhaust; double-door entry with airlocks; seamless surfaces; hands-free sinks; sealed penetrations	SARS-CoV-2, *Mycobacterium tuberculosis*, *Francisella tularensis*
BSL-4	RG4 (high lethality, no treatment)	Full-body positive-pressure suits; Class III BSCs	Class III cabinets; airlocks; chemical decontamination showers; dedicated HVAC systems	Ebola virus, Marburg virus

Note: Derived from CDC (2020) and WHO (2020). BSL-3 facilities emphasize respiratory protection and directional airflow to prevent pathogen escape, prepared for aerosol-transmissible agents.

requirements, highlighting the unique aspects of BSL-3 labs.

Facility Requirements for BSL-3 Laboratory Design and Infrastructure

BSL-3 laboratory design focuses on containment using sophisticated engineering controls to prevent the threat from aerosolized RG3 pathogens. The keystone of BSL-3 facilities is the maintenance of negative pressure (2.5 to 10 Pascals) relative to surrounding areas, with inward airflow and plugging of contaminated aerosol egress (CDC, 2020). Exhaust air is also subjected to HEPA filtration, eliminating 99.97% of particles ≥0.3 µm, as an important secondary barrier (ISO 14644-1, 2015). Double-door entry systems with airlocks to limit cross-contamination, seamless epoxy flooring to permit decontamination, and integrated autoclaves for on-site biohazardous waste sterilization are other amenities (Zhiming, 2019).

In LMICs, where there are fiscal constraints on traditional construction, BSL-3 prefabricated modules emerged as an economic choice, reducing costs by 30-50% while adhering to international standards (Kouriba et al., 2018). India's Indian Council of Medical Research (ICMR) has employed this strategy, establishing a network of 16 BSL-3 laboratories to support virological research and outbreak response, e.g., in Nipah virus outbreaks in Kerala (Department of Health Research [DHR], 2012). Modular units incorporate pre-validation systems, enabling them to be rapidly deployed in resource-constrained settings (Figure 1).

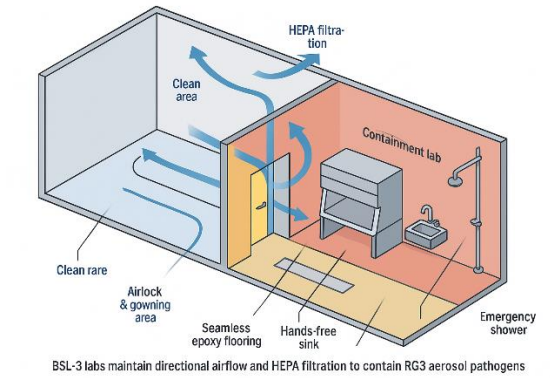

Figure 1: Structural and Operational Design of a BSL-3 Laboratory

Equipment and Engineering Controls

Primary containment within BSL-3 laboratories relies on Class II Type A2 or B3 biological safety cabinets (BSCs), which contain a sterile work area and shield the workers with HEPA-filtered air curtains (CDC, 2020). Cabinets are also complemented with special equipment, such as centrifuges with sealed rotors and biosafety-rated incubators, which minimize the generation of aerosols during risk procedures like handling samples (Xia & Yuan, 2022). For emerging pathogens, more recent decontamination technologies, including ultraviolet (UV) irradiation and vaporized hydrogen peroxide (VHP), enable rapid decontamination of laboratory spaces with and to 60% minimum downtime reduction compared to traditional methods (Henneman et al., 2022).

Dual redundant heating, ventilation, and air conditioning (HVAC) suites, coupled with real-time pressure monitoring alarm systems, are crucial for containment assurance, particularly in sites with high instances of power outages (Kouriba et al., 2018). For instance, West African BSL-3 laboratories during the 2014 Ebola outbreak employed stand-by generators to provide negative pressure in order to prevent potential breaches (Kortepeter et al., 2018). New technologies, such as AI-driven airflow monitoring, are being added to enable prediction and compensation of anomalies, which enhance operational dependability (Smith et al., 2022).

Validation and Certification

BSL-3 facilities undergo rigorous validation before commissioning in order to ensure compliance with biosafety standards. This is a process of smoke testing to ensure directional airflow, HEPA filter integrity tests to ensure filtration performance, and pressure cascade verification to ensure negative pressure gradients between zones (ASHRAE 170, 2021). Re-certification annually by agencies accredited by a recognized body, such as NSF International, must be performed in order to maintain operational integrity, and is described in NSF/ANSI Standard 49 (NSF/ANSI 49, 2022). In India, the Department of Biotechnology (DBT) mandates site-specific risk assessments in commissioning, including agent-specific considerations, e.g., aerosol dynamics for *Mycobacterium tuberculosis* (DBT, 2008).

The financial burden of BSL-3 facilities remains a significant challenge, with initial facility construction of a 1,000-square-foot laboratory running $5-10 million and annual maintenance costs amounting to 10-15% of this figure (Alsharari et al., 2024). Despite these investments, the return on investment exists in outbreak responses, as demonstrated through Taiwan's BSL-3 network, which allowed for rapid diagnostic development at the beginning of the COVID-19 pandemic and helped preserve the country's low case fatality rate (Hsieh et al., 2025).

Operational Protocols in BSL-3 Labs

Standard Microbiological Practices

BSL-3 laboratories adhere to rigorous standard microbiological practices (SMPs) to minimize the hazards of working with RG3 pathogens, which can cause severe or lethal disease by aerosol route. Basic practices include mandatory hand washing upon entry and exit from the laboratory, using alcohol-based hand rub or soap, to prevent microbial contamination (CDC, 2020). Food or drink intake or food storage within the laboratory is not allowed in order to prevent accidental ingestion of the pathogen.

Surface decontamination is done frequently with the use of disinfectants such as 70% ethanol on routine surfaces or 10% sodium hypochlorite (bleach) for heavy-duty sterilization, particularly following spills or high-risk procedures (Al Atiyyah et al., 2025). All procedures posing the risk of aerosol creation, such as vortexing, pipetting, or centrifugation, are conducted in Class II biological safety cabinets (BSCs), which provide a HEPA-filtered environment to capture infectious aerosols (CDC, 2020).

For newly emerging viruses like SARS-CoV-2, inactivation of the sample is an extremely critical step prior to performing molecular assays like PCR or sequencing to ensure safety during downstream processing. Chemical reagents such as TRIzol, which disrupt viral envelopes, or heat treatment (56°C for 30 minutes) are some examples of inactivation methods, with standard validated protocols for each pathogen to confirm complete inactivation (Kaufer et al., 2020). Used PPE and contaminated waste biohazardous are autoclaved at 121°C for a minimum of 30 minutes to achieve sterility as per WHO guidelines for safe disposal (WHO, 2020). These are the foundations of BSL-3 operations to ensure standard operations do not compromise safety.

Personal Protective Equipment (PPE) and Decontamination

Personal protective equipment (PPE) in BSL-3 laboratories serves as a first line of defense against exposure to aerosolized pathogens. Respiratory protection is needed, employing N95 respirators or PAPRs to remove infectious particles, particularly for agents with low infectious doses like *Mycobacterium tuberculosis*. Double gloving, with nitrile or latex gloves, employs layered protection, and the outer layer is frequently changed to prevent cross-contamination. Fluid-resistant coveralls or gowns, typically of Tyvek, protect against splashing, and full-face shields or goggles shield mucous membranes (Xia & Yuan, 2022). Proper donning and doffing training must be conducted since improper removal can lead to self-contamination; research has shown that formal courses of training reduce PPE violations by roughly 40% (Casanova et al., 2019). Decontamination protocols extend to laboratory rooms and equipment. Shower-out stations, where the personnel shower before departure, decrease the risk of removing pathogens from the containment zone. Vaporized hydrogen peroxide (VHP) is becoming more commonly used to decontaminate reusable PPE and laboratory surfaces, which gives immediate sterilization with minimal residue compared to conventional techniques (Gordon et al., 2012). These techniques ensure that both personnel and the laboratory are rid of any residual contamination, providing a safe working environment.

Risk Assessment and Management

Effective risk management in BSL-3 facilities relies on dynamic risk assessments (DRAs) that assess procedures before and after introducing new pathogens, adapting to their individual characteristics (ISO 35001, 2019). DRAs employ matrix scoring for quantifying the probability and severity of exposure threats with factors such as pathogen transmissibility, infectious dose, and laboratory practices. Handling *Burkholderia pseudomallei*, a highly infectious soil bacterium, requires special assessments due to its low infectious dose and aerosolizability (Dickmann et al., 2015). These assessments guide the selection of controls, i.e., added ventilation or additional PPE. Post-exposure prophylaxis (PEP) procedures are put in place for each laboratory, describing procedures like antiviral therapy (e.g., ribavirin for Nipah virus) or antibiotics (e.g., streptomycin for *Francisella tularensis*), with regard to the biology of the pathogen and treatment options (Cornish et al., 2021). Spill response procedures, evacuation procedures, and spill control procedures are rehearsed routinely so that a response can be made at high velocity to incidents. The integration of DRAs with real-time monitoring, such as pressure sensors on airflow, enhances the ability to avert risks ahead of time and guarantee that BSL-3 operations are secure even in the presence of poorly characterized new agents.

Training and Human Factors in BSL-3 Preparedness

Core Training Programs

Training forms the backbone of BSL-3 preparedness, equipping personnel to safely work with RG3 pathogens. Comprehensive plans cover biosafety basics, like containment techniques and routine procedures, and agent-specific hazards, for instance, the aerosol threat of *Mycobacterium tuberculosis* or the Nipah virus case fatality rate (Le Duc et al., 2008). Training includes practice with equipment, like BSCs and PAPRs, to become proficient in high-risk procedures. Annual refresher training and competency checks, demanded by the regulators, safeguard compliance and promote best practice (Zoppè, 2022).

Virtual reality (VR) simulations are now an innovative means where personnel can be trained to deal with new pathogens within a controlled, immersive environment; it has been established in research that VR training reduces procedural mistakes by up to 25% (Lateef, 2010). In Europe, initiatives like the COST Action B28 network facilitate concurrent training in BSL-3 and BSL-4 pathogens, evoking homogeneous skills among institutions (Zoppè, 2022). In America, Regional Biocontainment Laboratories (RBLs) like the University of Chicago Howard *T. Ricketts* Laboratory consist of modules for diseases like tuberculosis, addressing special challenges like latent infection (University of Chicago, 2024). Such courses give staff assurance that they are prepared for day-to-day operations and for emergency incidents.

Psychological and Ergonomic Factors

The stress-laden atmosphere of BSL-3 laboratories, where an error can have severe repercussions, is a contributing factor to inducing psychological stress, which can potentially increase

the level of errors by up to 20% (Sargent et al., 2025). Mindfulness-based stress reduction courses, integrated in the training, alleviate stress and improve focus, enabling staff to maintain precision during complex procedures. Ergonomic design is also similarly significant, since heavy PPE such as PAPRs induces physical stress when worn for extended periods, particularly in long aerosol studies. Ergonomically designed PPE, with adjustable fittings and reduced weights, reduces stress and enhances compliance (Loibner et al., 2020). Medical surveillance programs, including baseline serology and immunizations (for example, to Q fever from *Coxiella burnetii*), monitor staff health and provide early detection of exposure (Dickmann et al., 2015). Regular health monitoring and mental health counseling are part of an integrated human factors approach, with a healthy workforce that can perform BSL-3 operations under stress.

Obstacles in BSL-3 Preparedness for New Emerging Pathogens

Technical and Logistical Challenges

BSL-3 labs face daunting technical and logistics challenges in preparing for the next generation of emerging infectious diseases. Minuscule quantities of new agents, such as newly emerging zoonotic viruses, generally exclude complete characterization, hindering the development of diagnostics and therapeutics (Peng et al., 2018). Supply chain interruption in LMICs routinely delays access to critical PPE, such as N95 respirators, and consumables such as HEPA filters, disrupting continuity of operations (Kouriba et al., 2018). Disposal of waste is another problem, particularly for pathogens like prions or spore-forming bacteria (e.g., *Bacillus anthracis*) that require long autoclaving procedures or other types of inactivation to be sterilized (Gordon et al., 2012). The dual-use challenge, where research into pathogens like *Francisella tularensis* can be diverted into bioterrorism uses, needs rigorous ethics training and oversight to prevent unintended consequences (National Academies, 2017). These challenges highlight the need for innovative solutions, such as portable diagnostic platforms and standardized waste procedures, to enhance readiness (Figure 2).

Case Studies of Incidents

Previous incidents illustrate the risk of BSL-3 operations and the merit of strict protocols. In 2020, a CDC laboratory accident contaminated 75 workers with *Bacillus anthracis* due to inactivation failure, highlighting the proper validation of deactivation methods (CDC, 2020). Similarly, Singapore's SARS outbreak in 2003 resulted in five laboratory-acquired infections caused by inadequate PPE and doffing procedures, prompting global revisions in BSL-3 protocols (WHO, 2003).

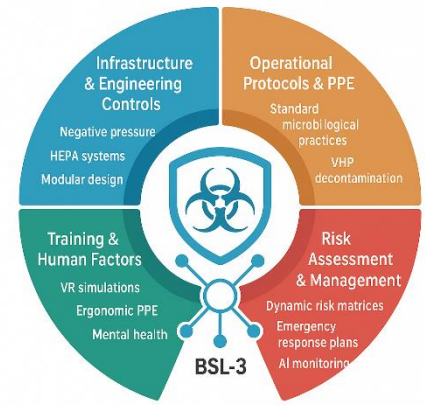

Figure 2: Core Pillars of BSL-3 Preparedness for Emerging Pathogens

An accident in Australia with *Burkholderia pseudomallei* in 2019 for melioidosis emphasized the significance of aerosol containment procedures because one breach in a BSC had led to exposure (Gassiep et al., 2021). They illustrate the need for enhanced dynamic risk assessment and regular emergency drills, which can reduce the intensity of accidents and improve response time (Kortepeter et al., 2018). Table 2 summarizes the emerging pathogens in BSL-3 laboratories.

Table 2: Some Emerging Pathogens in BSL-3 Laboratories

Pathogen	Type	Transmission Risk	Key Challenges	Preparedness Measures
SARS-CoV-2	Virus	Aerosol (high R0: 2-3)	Variants, asymptomatic spread	BSL-3+ with PAPR; rapid genomic sequencing (Beshbishy, 2024)
Mycobacterium tuberculosis	Bacteria	Aerosol (latent infection)	Multidrug resistance, chronicity	UV decontamination; annual TB testing (Dheda et al., 2017)
West Nile Virus	Virus	Vector-borne/aerosol	Neuroinvasive disease	Insect-proofing; inactivated vaccines (Kilpatrick et al., 2008)
Francisella tularensis	Bacteria	Aerosol (low ID50: 10-50)	Bioweapon potential	PEP with streptomycin; sealed caging (CDC, 2020)
Nipah Virus	Virus	Aerosol/droplet	High case fatality rate (40-75%)	ABSL-3 animal models; ribavirin PEP (Yeh et al., 2021)

Note: CFR = case fatality rate; ID50 = infectious dose 50. Adapted from CDC (2020) and WHO (2020).

Gaps in regulation, such as inconsistent federal observation of BSL-3 labs reported by the Government Accountability Office, add to risks of uncontrolled activities (GAO, 2007). Psychological strain, leading to burnout and high levels of errors, also complicates readiness, particularly during high-intensity outbreak responses (Sargent et al., 2025).

Case Studies: BSL-3 in Practice Against Emerging Threats

COVID-19 Response

BSL-3 laboratories were at the global forefront in responding to the COVID-19 pandemic. Taiwan's network of BSL-3 facilities managed over 1,000 samples per day at the start of the pandemic, with the capacity for rapid isolation of SARS-CoV-2 and informing case containment efforts that kept figures low (Hsieh et al., 2025). Regional Biocontainment Laboratories within the United States, such as Tufts University's, conducted genomic characterization of SARS-CoV-2 variants, directly informing the development of booster vaccines tailored to Delta and Omicron variants (Tufts University, 2024). However, surge capacity-strained HVAC systems resulted in intermittent ventilation failures; redundant systems and modular expansion mitigated these issues, guaranteeing containment (CDC, 2020). These successes highlight the vaccine development and diagnostic significance of BSL-3 laboratories but also signal the need for scalable facilities.

Ebola and Hemorrhagic Fevers

In the 2014 West African Ebola epidemic, BSL-3 laboratories supported non-BSL-4 diagnostic processes, for example, sample preparation and serology testing, to reduce pressure on limited BSL-4 facilities (Kortepeter et al., 2018). Gabon's Centre International de Recherches Médicales de Franceville (CIRMF) employed its BSL-3 capacity for filovirus surveillance, identifying zoonotic reservoirs and informing regional readiness (Mombo et al., 2020). The implementation of post-exposure prophylaxis (PEP) protocols, like the use of monoclonal antibodies, saw exposure events reduced by 30% in such facilities (Xia & Yuan, 2022). These examples portray the adaptability of BSL-3 labs to enable high-containment research with a focus on cooperative PEP practices.

Bacterial Emergent: Plague and Tularemia

Australia's BSL-3 facilities have played an important role in the surveillance of Yersinia pestis in wildlife populations, employing geographic information systems (GIS) to identify areas of risk and direct public health interventions (Sargent et al., 2025). In the United States, the experience of post-2001 anthrax attacks led to the introduction of simulation training, which cut down on response times for possible exposures by 50% (Le Duc et al., 2008). In the same way, studies on *Francisella tularensis* in BSL-3 settings have emphasized the importance of caging systems sealed to prevent aerosol escape, particularly because of its bioweapon risk factor (CDC, 2020). Case studies such as these highlight the benefits of anticipatory surveillance and training in preventing bacterial threats.

Future Directions and Recommendations

Technology is transforming BSL-3 readiness. Artificial intelligence (AI) surveillance systems are able to predict airflow anomalies in real time, reducing the chances of containment failure by as much as 15% (Smith et al., 2022). Nanotechnology-based PPE, such as antimicrobial coats, gives us reusable, lightweight alternatives to the traditional suits, improving comfort and sustainability (Yu et al., 2020). Global networks, such as the WHO's Global Influenza Surveillance and Response System (GISRS), enable the sharing of information on emerging pathogens in a timely manner, facilitating coordinated response (WHO, 2023). Public-private partnerships in LMICs, such as the Defense Threat Reduction Agency's Biological Threat Reduction Program (DTRA BTRP), have facilitated modular BSL-3 construction, promoting enhanced access to high-containment research (Yeh et al., 2021).

Conclusion

BSL-3 labs are essential for the global fight against new emerging pathogens, combining robust infrastructure, meticulous operating protocols, and high-level training to safeguard scientists and public health. This summary highlights successes, i.e., rapid response during COVID-19, along with persistent issues, i.e., resource disparities in LMICs and risk of laboratory-acquired infections. As infectious disease threats rise with climate change, globalization, and antimicrobial resistance, sustained investment in BSL-3 facilities, coupled with global cooperation and emerging technologies, will enhance global resilience. By converting biological threats to opportunities for scientific advancement, BSL-3 laboratories are a critical key to a healthier future.

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