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Operational Management and Lessons from the Sierra Leone–China Friendship Fixed Biosafety Laboratory

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Case Report

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Abstract

High-level biosafety laboratories are vital for preventing, controlling, and responding to infectious diseases, and they are critical barometer of a nation's public health security. Countries are actively building their capacities to contribute to public health security at national, regional, and global levels. Using a case study approach, this paper develops a three-dimensional analytical framework—comprising "framework, mechanisms, and outcome indicators"—to systematically analyze the management practices of the Sierra Leone–China Friendship Permanent Biosafety Laboratory. The study identifies three key mechanisms underpinning its sustainable operation: a risk-oriented systemic framework, a progressive tiered mechanism for talent cultivation, and diversified funding and cooperation models. This case offers valuable insights for building and managing foreign-aid laboratories, contributing to stronger public health security in recipient countries and greater stability in regional public health security.

1. Introduction

The Self-Assessment Annual Reporting (SPAR) tool, developed by WHO for States Parties to assess their core capacities under the International Health Regulations, and the Global Health Security (GHS) indicator system (e.g., from Johns Hopkins University) both list laboratories and testing as essential indicators. The latest Africa Health Security (AHS) report shows that Africa's average health security score (out of 100) increased from 32.4 to 41.5 in 2026, with a substantial gains in laboratory systems. In contrast, the average scores for biosafety and biosecurity were merely 18.2 and 14.9, respectively. This indicates that merely augmenting physical infrastructure does not automatically guarantee improved health security[1].

Within the global public health security network, high-level biosafety laboratories—i.e., Biosafety Level 3 (BSL-3) and above—are critical requirement in the early detection and rapid response to emerging and re-emerging infectious diseases. According to incomplete statistics, over 3,500 BSL-3 facilities exist across 149 countries; however, approximately 82% of this high-level biosafety capacity is concentrated in high-income countries. Many BSL-3 laboratories in low- and middle-income countries, built with foreign investment or aid, often encounter the dilemma of “peaking at completion and deteriorating after commissioning,” driven by the withdrawal of follow-up funding, limited local technical expertise, and a lack of management systems. This phenomenon is vividly termed the “funding cliff” in the field[2].

Studies on laboratory pairing and sustainable development indicate that externally funded laboratory capacity building often lacks durable institutional arrangements, and operational quality tends to decline after donor withdrawal[3, 4]. Although there has been extensive discussion regarding increased investment in laboratory infrastructure within the global health security sector, evidence concerning the sustainable operation of donor-funded BSL-3 laboratories remains scarce. Existing research has largely focused on technical capacity assessments or emergency outbreak responses, but lacks systematic analysis of governance mechanisms across the life cycle of aid-funded laboratories—particularly limited

empirical research on key sustainability mechanisms, such as resource mobilization, talent development, and the localization of standards. Accordingly, this study addresses the following questions: (1) How can donor-funded BSL-3 laboratories establish a sustainable operational framework? (2) Which institutional mechanisms contribute to their long-term sustainability? (3) Are these experiences generalizable to other donor-funded laboratory settings?

The Sierra Leone–China Friendship Biosafety Laboratory (hereinafter referred to as the “Sierra Leone–China Friendship Laboratory”) is a permanent BSL-3 facility constructed with assistance from the Chinese Government following the 2014 Ebola outbreak in West Africa. It was officially commissioned in March 2015[5, 6] and serves as a representative case study for addressing the research questions outlined above, providing a solid empirical basis for this investigation.

In 2025, the World Health Assembly adopted the WHO Pandemic Agreement, making it the second legally binding instrument for Member States after the International Health Regulations (IHR). Article 12 of the Agreement, which addresses pathogen access and benefit-sharing, lies at the core of the entire accord. It requires relevant specialist laboratories not only to meet technical capacity requirements but also to comply with international and national standards for biosafety and biosecurity[7]. In this context, a critical question emerges: how can public health laboratories in Africa fulfil the requirements set out in the annexes to the Pandemic Agreement? By synthesising the practical management experience gained from foreign-aid-supported high-level biosafety laboratories, we can identify viable pathways to address this need—ensuring both the sustainable operation of these laboratories and their meaningful engagement in global public health governance.

2. Study Design and Methods

This study adopts a case study approach, using the Sierra Leone–China Friendship Laboratory as a single case to systematically examine its full life-cycle governance mechanisms since its commissioning in March 2015.

2.1 Analytical Framework

A three-dimensional analytical framework was constructed comprising "framework," "mechanisms," and "outcome indicators." The "framework" dimension focuses on the laboratory's system design and risk management structure. The "mechanisms" dimension centres on sustainable operational mechanisms, including talent development, resource mobilisation, and standards localization. The "outcome indicators" dimension employs comparable quantitative benchmarks to assess the effectiveness of the laboratory's capacity-building efforts.

2.2 Data Sources

Data were obtained from three categories of sources: (1) official laboratory archives, consisting of four tiers of system documentation—management manuals, procedural documents, standard operating

procedures (SOPs), and work records; (2) project reports and evaluation documents, covering implementation reports, monitoring and evaluation data, and records of research outputs from the three phases of the assistance programme; and (3) publicly available literature, including peer reviewed journal articles and reports published by the WHO and the Africa Centres for Disease Control and Prevention (Africa CDC).

2.3 Timeframe

This study covers the laboratory's complete operational cycle from its official commissioning in March 2015 through to the end of 2025, encompassing the three phases of the assistance programme.

2.4 Definition of Key Outcome Indicators

The following comparative indicators are employed to evaluate the laboratory's development performance: (1) testing capacity expansion, measured by the number and types of detectable pathogens; (2) talent development, measured by the number of training sessions, number of trainees, size of the local team, and educational attainment of its members; (3) workload, measured by the proportion of national sample testing tasks undertaken; and (4) research output, measured by the number of published papers and the number of patents commercialised.

3. Results

3.1 System Operation and Risk Management

At the design stage, the Sierra Leone–China Friendship Laboratory divided its experimental area into four functional zones[8], drawing on the WHO Laboratory Biosafety Manual, relevant standards from the Chinese Center for Disease Control and Prevention, and the highly pathogenic transmission characteristics of the Ebola virus. The design follows a risk management logic of "progressively decreasing laboratory pressure and multi-layered personnel protection." The laboratory has established a four-tier documentation system comprising a management manual, procedural documents, standard operating procedures (SOPs), and work records. Over time, its operational approach has evolved from passive rule-following to proactive risk assessment, with regular safety inspections and environmental monitoring enabling early risk identification and source control. In terms of quality management, the laboratory has developed a comprehensive quality management system framework aligned with the Africa Centres for Disease Control and Prevention (Africa CDC) star-rating criteria. This framework consists of four levels—quality manual, procedural documents, SOPs, and record forms—and work has already begun to systematically review and refine each indicator against the star-rating requirements (Fig. 1).

3.2 Sustainable Operational Mechanisms

3.2.1 Talent Development Mechanism

In the early stages of the aid programme, almost all laboratory testing personnel, for operations, maintenance, and support staff, were from China. Over the past decade, the Sierra Leone–China Friendship Laboratory has bridged the professional capacity gap in Sierra Leone's public health sector, medical institutions, and high-level biosafety laboratories by establishing a training model characterized by "progressive tiering with a combination of targeted and comprehensive approaches." As a result, a stable local team of Sierra Leonean laboratory staff has been established, now independently undertaken routine operations and key testing tasks.

3.2.2 Funding and Cooperation Mechanisms

During its initial establishment, all construction and operational funding for the laboratory was provided by the Chinese Government. Since 2015, the laboratory has progressed through three phases: Phase I (2015–2017), focusing on Ebola control and basic capacity building; Phase II (2017–2020), expanding into multi-pathogen surveillance and local talent development; and Phase III (2021-present), centring on COVID-19 response and the co-establishment of a "Belt and Road" Joint Laboratory[8]. In 2021, building on the existing funding model, a trilateral cooperation framework was established among China, Sierra Leone, and the Gates Foundation: the Chinese side provides technical solutions and expert support, Sierra Leone serves as the implementation platform, and the Gates Foundation contributes funding and introduces international management expertise [6].

3.3 Outcome Indicators

Expansion of testing capacity: The laboratory's testing capacity has expanded from initially detecting only the Ebola virus to now covering 26 viruses, 10 bacteria, and malaria parasites (Table 1). The total number of detectable pathogen types has increased from 1 to 37 (including bacterial culture), and testing techniques now encompass a range of methods, including PCR, molecular sequencing, microbial culture, and antimicrobial susceptibility testing.

Table 1
Testing Capabilities of the Sierra Leone–China Friendship Fixed Biosafety Laboratory

No.	Test items	Test Method
1	EBOLA	PCR
2	LASA	PCR
3	MARBURG	PCR
4	YELLOW FEVER	PCR
5	MPOX	PCR
6	COVID-19	PCR
7	RIFT VALLEY	PCR
8	DENGUE	PCR
9	ZIKA	PCR
10	MALARIA	Malaria RDT, Microscopy & Sequencing
11	BACTERIAL CULTURE	Antimicrobial Susceptibility Testing

Achievements in human resources development

A total of 1,061 Sierra Leonean personnel have been trained across 37 training courses. Through a mentorship programme, 19 key technical staff have been developed, five of whom have been funded to pursue degree studies in China. A stable local team of 13 Sierra Leonean members has now been established (Fig. 2). The proportion of local staff has risen from nearly zero at the time of the laboratory's establishment to 100% of the current team.

Workload indicators: During the 2024–2025 monkeypox outbreak, the laboratory tested over 50% of samples nationwide in Sierra Leone, and the majority of the test was done by the Sierra Leonean saff. This demonstrates that the local team has developed the capacity to to handle the country’s core testing task independently

Research output and commercialisation: With support from the "Belt and Road" Joint Laboratory project, a total of 19 research papers have been published, one invention patent has been filed, and commercialisation of the technology has been achieved. The integrated sequencing and analysis platform developed by the Chinese side has reduced the time required for malaria molecular epidemiological testing from several weeks to a few hours, substantially improving testing efficiency.

Diagnostic quality enhancement: The laboratory sequenced the first complete genome of Salmonella typhi in Sierra Leone, correcting previous misdiagnoses and demonstrating its substantial contribution to diagnostic accuracy[8].

4. Discussion

Through this case study, three key mechanisms for the sustainable operation of the Sierra Leone–China Friendship Laboratory have been identified: a risk-oriented systemic framework, a tiered talent development mechanism, and a diversified funding and cooperation model.

The tiered talent development mechanism stands as a broader application potential Through a three-stage pathway—comprising "grassroots training, key personnel mentoring, and team building"—this mechanism addresses the shortage of qualified personnel in high-level biosafety laboratories in low- and middle-income countries. Similar mechanisms could be applied to laboratory capacity-building in countries such as Senegal, Gabon, or Angola, which also host donor-funded BSL-3 facilities. These countries face similar challenges of post-construction talent drain and declining operational capacity, and the Sierra Leone-China Friendship Laboratory experience can offer a reference framework for talent development.

A diversified funding model is an essential prerequisite for the sustainable development of foreign-aid laboratories. The trilateral "China–Sierra Leone–Gates Foundation" cooperation model has effectively reduced reliance on funding from a single donor by introducing international foundation funding and management expertise. This model could be adopted by laboratories funded by other donors (e.g., the U.S. President's Emergency Plan for AIDS Relief (PEPFAR) or the European Union), to enhancing financial sustainability through a multi-stakeholder cooperation framework.

Risk-oriented systemic frameworks, however, require localisation to fit specific national contexts. The Sierra Leone–China Friendship Laboratory indicates that international standards, domestic management experience, and expert consensus must be adapted to local conditions, rather than simply replicating "best practice" standards. Foreign-aid laboratories should actively participate in and promote the systematic enhancement of the recipient country's biosafety governance capacity, ensuring that individual laboratories become integral components of the national biosafety system[9]. This principle offers a useful reference for the standard localisation process in laboratories funded by other donors.

Future foreign aid projects should incorporate a "comprehensive, end-to-end, full-chain, full-cycle"[10] governance framework from planning and designing stages onward. Through quantitative risk assessment, alignment with international standards, dual quality control, and full life-cycle infrastructural management, this framework establishes a closed-loop logic that integrates risk identification, institutional design, process control, infrastructure assurance, and dynamic feedback. Embedding this theoretical framework at the outset of the full cycle will help to upgrade the foreign aid model from an "experience-based" to a "theory-informed" approach, thereby establishing a new paradigm for research on foreign aid.

This study has the following limitations. First, as a single-case study, the Sierra Leone -China Friendship Laboratory experience may be influenced by specific political, economic, and the Sierra Leone health system context,, and the generalisability of its conclusions requires further validation. Second, as this

study is primarily based on publicly available archives and literature from the donor's perspective, it may not fully reflect the perspectives and priorities of other stakeholders within the recipient country's health system (e.g., the Ministry of Health, other donors, and communities). Third, as this study is primarily a secondary analysis based on archival documents and publicly available literature, it did not conduct in-depth interviews with laboratory staff or health sector managers in the recipient country, and may therefore have omitted some important qualitative information.

5. Conclusion

Based on a systematic analysis of the ten-year operational practice of the Sierra Leone–China Friendship Biosafety Laboratory, this study draws the following conclusions. First, the sustainable development of donor-funded BSL-3 laboratories depends on the autonomous operational capacity of local technical teams, and a tiered, progressive talent development mechanism is the key pathway to achieving this. Second, a diversified funding mechanism—including trilateral cooperation models—can reduce reliance on a single donor's support and strengthen the sustainability of laboratory operations. Third, proactive alignment with international quality and safety standards, combined with their localisation to national contexts, is a critical safeguard for the long-term sustainable laboratory operations.

Abbreviations

AHS
Africa Health Security
Africa CDC
Africa Centres for Disease Control and Prevention
BSL-3
Biosafety Level 3
GHS
Global Health Security
IHR
International Health Regulations
PCR
Polymerase Chain Reaction
PEPFAR
President's Emergency Plan for AIDS Relief
SLCL
Sierra Leone–China Friendship Laboratory
SOPs
Standard Operating Procedures
SPAR
Self-Assessment Annual Reporting
WHO

World Health Organization

Declarations

Ethics approval and consent to participate

This study did not involve human or animal subjects, nor did it involve the collection or use of personal privacy data or biological samples. Therefore, ethical approval and informed consent were not required.

Consent for publication

Not applicable.

Availability of data and materials

All data and materials cited in this manuscript are derived from publicly available sources, including peer-reviewed literature, organizational reports, and official webpages, all of which have been annotated in the references section. No unpublished data or proprietary materials were used.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

YG drafted the manuscript. JD, HJW, and CPZ performed the conceptual analysis. HYS, JW and LLW contributed to the study design. DH, AT, and ILK provided resources and local expertise. YHW supervised the study and reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Figures

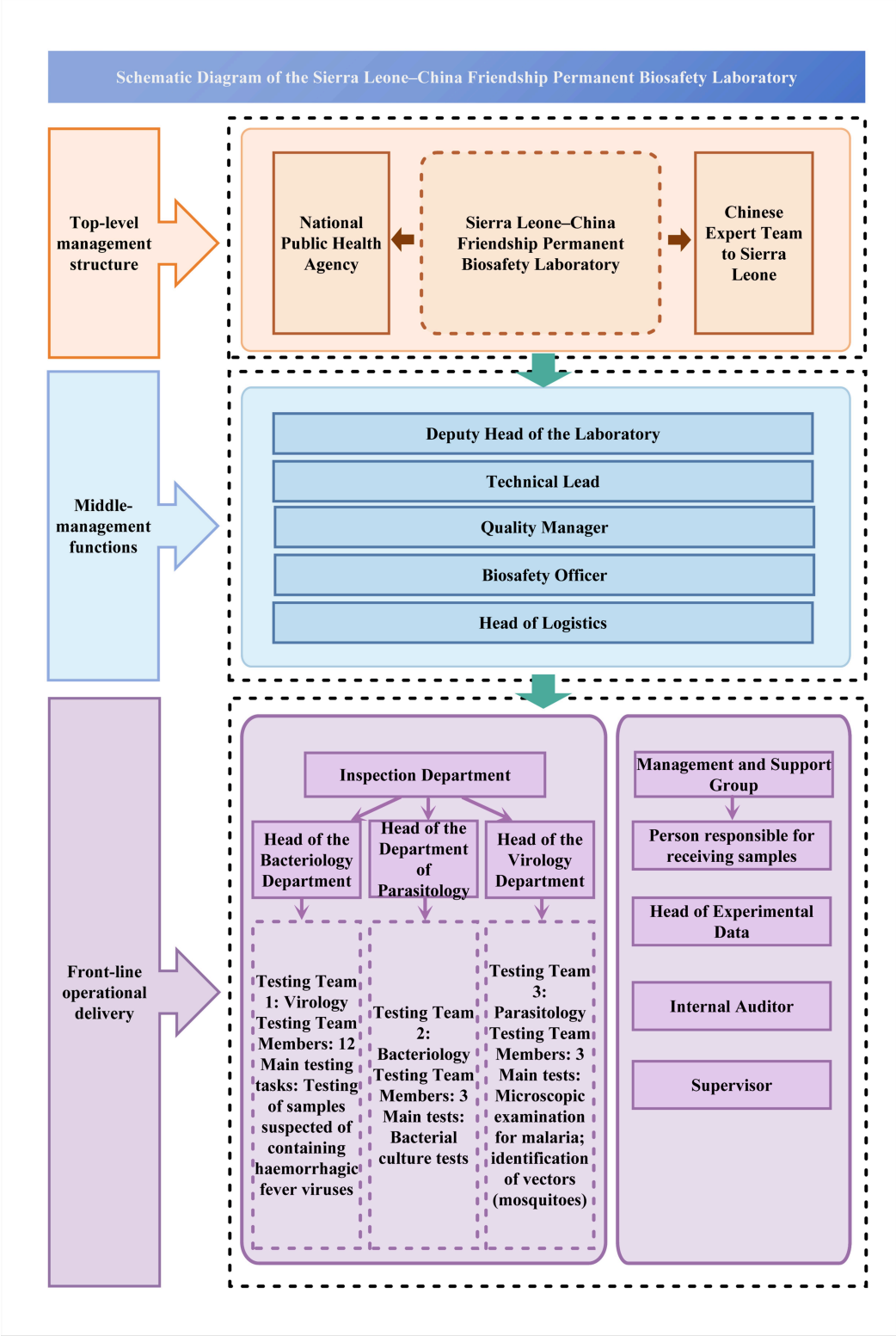


Figure 1

Chart showing the team's educational backgrounds and role distribution

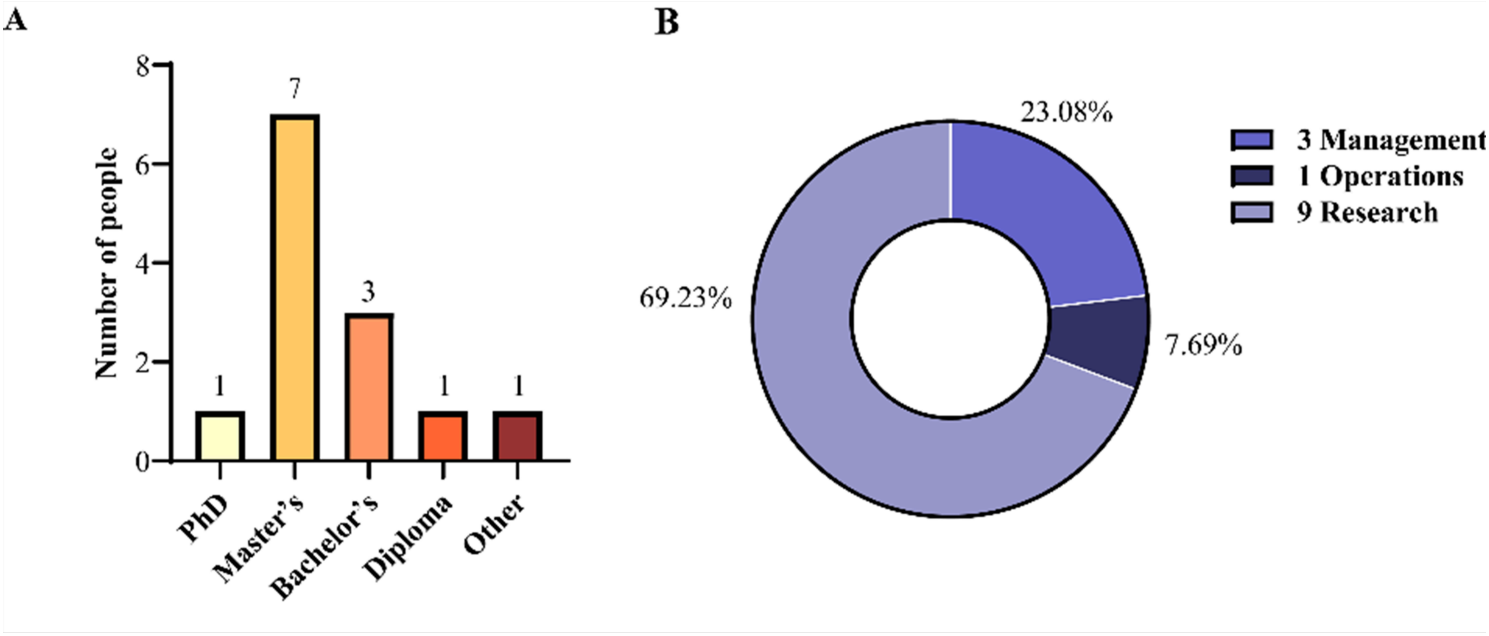


Figure 2

Chart showing the team's educational backgrounds and role distribution