SUMMARIZED REPORT ON NATIONAL INVENTORY OF DANGEROUS PATHOGENS AND TOXINS IN MALI

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About the National Inventory of Dangerous Pathogens and Toxins Project

The Government of Mali recognizes the importance of Strengthening its disease surveillance and response capabilities. As part of the REDISSE III project, Mali is undertaking the establishment of a **National Inventory of Dangerous Pathogens and Toxins (INPD).** This initiative involves identifying stakeholders responsible for the inventory, cataloguing dangerous pathogens present within the country, and developing a comprehensive database for their tracking and management. The technical execution of this endeavour falls under the purview of the **National Institute of Public Health (INSP)**, with a consultant tasked to develop the necessary tools.

The main objective is to establish a INPD in Mali, with specific objectives including the identification of government entities and national stakeholders responsible for the inventory, the compilation of dangerous pathogens present in Mali, the creation of a detailed database encompassing these pathogens, and the implementation of a functional framework for regular database maintenance and updates.

Preface

This project is for the Government of Republic of Mali through the Ministry Health and Social Development. The National Inventory of Dangerous Pathogens and Toxins Project is coordinated by Ms. Kadiatou DAO, Biosafety and Biosecurity Officer at INSP (kdidao@gmail.com) and was undertaken by Dr. Stephen Obol OPIYO (sopiyo@patiradatascience.com), of Patira Data Science, LLC, Westerville, Ohio, USA.

Funding for this initiative comes from the World Bank via the Regional Project For Strengthening Disease Surveillance Systems in Africa, The West (REDISSE)-THIRD PHASE. For additional details, contact the Project Coordinator Dr. Seydou GOITA (seydougoita@hotmail.com).

Stephen Opiyo extends deep gratitude to The Government of the Republic of Mali, the Ministry of Health and Social Development, REDISSE III, the World Bank, and INSP for their unwavering cooperation and support throughout this endeavour. Special thanks go to the Director-General of INSP, Dr. Ibrahima GUINDO, as well as all INSP staff, particularly (Ms. Kadiatou DAO, Dr. Issa CISSE, Dr. Souleymane Coulibaly, Ms. Wadia KARAMBE, Dr. Kone Klema MARCEL, Mr. Diarra ABOUBACAR, and Ms. Nana KOUMA), and all others who provided invaluable information during labs visits. Recognition is also due to Mr. Benjamin KASSOGUE for his consistent assistance as a translator from the project's inception.

Executive summary

The government through the Ministry of Health and Social Development intends to develop a INAPD in Mali. International evidence has shown that the Ministry of Health's success in achieving this objective will depend on four key factors:

1. *Stakeholders,* including the entities that stores dangerous pathogens and toxins.
2. Lists of dangerous pathogens and toxins in Mali.
3. *Tools for collecting data* on dangerous pathogens and toxins.
4. *A database* for storing dangerous pathogens and toxins.

We were asked by REDISSE III to develop Mali INAPD, which we have done, relative to the four success factors mentioned above.

This study was conducted from February 25th to March, 28th 2024, and consisted of meetings, visiting of government labs, stakeholders' awareness workshop, training of laboratory technicians, focus group discussion, and desk-based research.

As discussed on the following pages, the government has many of the building blocks for success in developing INAPD, but significant improvements are needed in several areas. Below we summarize some of the key issues identified through our work. Additionally, we can collaborate with government of Mali in some areas, particularly in the realms of bioinformatics and data management, to help tackle some of these challenges effectively.

1. *Deficiency of Accident Protocols:* Deficiency of accident protocols at some laboratories raises concerns about emergency response preparedness.
2. *Need for Bioinformatics Capacity:* Some laboratories lack in-house bioinformatics capabilities, relying on external partners for data analysis.
3. *Inefficient Sample Tracking Protocols* : Some labs visited are inefficient in tracking samples, raising concerns about sample integrity and traceability.
4. *Necessity to strengthen Waste Disposal Mechanisms*: Some of the labs visited need strengthening in waste disposal mechanisms. The labs rely on heating waste to 80 degrees Celsius and depositing it in containers, posing environmental and safety concerns. Even though they have autoclaves.
5. *Inefficient Data Management Systems:* Some laboratories have inefficient data management systems, which can hinder research effectiveness and collaboration. This gap raises concerns about data integrity and research efficiency.
6. *Limited Awareness Among Key Stakeholders:* Some stakeholders, especially those in non-health-related sectors, may have limited awareness of the risks posed by dangerous pathogens and toxins. This limited awareness can hinder effective collaboration and resource mobilization.

We have identified and prioritised 12 specific recommendations. These are summarised in Table 1 below.

Table 1: Prioritised 12 specific recommendations we identified.

Area	Recommendation
Bioinformatics and Data Management	*Recommendation 1* Invest in internal bioinformatics expertise or partnerships to build in-house capacity for data analysis and interpretation. This includes training staff in bioinformatics techniques and establishing collaborative relationships with institutions like INSP to strengthen bioinformatics capabilities. INSP can partner with other labs to develop Bioinformatics core facility.
	Recommendation 2 Implement centralized systems to ensure data integrity, facilitate collaboration, and enhance research efficiency.
	Recommendation 3 The INSP team should monitor laboratories collecting with dangerous pathogens and toxins every six months for compliance.
	Recommendation 4 Maintain the update of WAMPServer and Windows 11. Collaboration among IT, Data, and Biosafety/Biosecurity personnel is vital for NIAPD's security. Maintaining update schedules, patch management, risk assessments, and backups mitigate vulnerabilities. Monitoring update statuses ensures timely action to safeguard against threats and disruptions.
Laboratories	*Recommendation 5* Outsource waste disposal to a third party for safe and environmentally friendly handling, such as incineration. Implement proper waste management protocols to ensure compliance with environmental regulations and minimize potential hazards.
	Recommendation 6 Invest in staff training in biosafety and biosecurity. Investing in staff training in biosafety and biosecurity is paramount for any organization operating in fields involving biological materials or research.
	Recommendation 7

	INSP should collaborate with pre-veterinary laboratories to tackle Antimicrobial Resistance (AMR) comprehensively. Through resource sharing and expertise exchange, ISNP can analyze samples collected by pre-veterinary labs.
	Recommendation 8 Implement a comprehensive sample tracking system using barcode technology or similar methods to ensure the accuracy, integrity, and traceability of samples throughout the testing process.
	Recommendation 9 Regularly train laboratory technicians in collecting information on dangerous pathogens and toxins, as well as understanding the factors influencing disease risk classification.
	Recommendation 10 Prioritize the development and implementation of formal accident protocols to strengthen emergency preparedness.
Stakeholders	*Recommendation 11* Conduct a thorough stakeholder analysis to identify and engage a diverse range of stakeholders, including those from sectors beyond public health. This mapping exercise should consider the roles, interests, and expertise of each stakeholder group to ensure comprehensive representation.
	Recommendation 12 Develop targeted awareness campaigns to educate key stakeholders about the risks associated with dangerous pathogens and toxins, as well as the importance of collaborative action.

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List of abbreviations

Africa CDC: The Africa Centres for Disease Control and Prevention.

CDC Atlanta: Centers for Disease Control and Prevention.

CICM: Charles Mérieux Infectiology Center.

CRISPR: Clustered Regularly Interspaced Short Palindromic Repeats.

IER: Institute of Rural Economy Sotuba Biotechnology Laboratory

INSP: The National Institute of Public Health.

LBMA: Applied Molecular Biology Laboratory.

LCV: Central Veterinary Laboratory

NIH: National Institute of Health.

PPE: Personal Protective Equipment.

REDISSE: Regional Disease Surveillance Systems Enhancement.

RIVM: National Institute for Public Health and the Environment**.**

UCRC: University Clinical Research Center of Mali.

UNCST: Uganda National Council of Science and Technology.

WAMP: Windows, Apache, MySql, PHP.

WHO: World Health Organization.

1 Introduction

1.1 Background of the Project

The Government of the Republic of Mali is prioritizing the enhancement of its disease surveillance and response capabilities through the REDISSE III project. As part of this initiative, Mali is actively working on establishing a National Inventory of Dangerous Pathogens (INPD). This effort entails identifying relevant stakeholders, cataloguing dangerous pathogens and toxins within the country, and developing a robust database for their monitoring and control. The technical implementation of this project is overseen by the INSP, with the assistance of a consultant tasked with developing essential tool.

As part of its drive to develop INPD, the REDISSE IIII Project Coordinator Dr. GOITA on behalf of the government asked Dr. OPIYO from Patira Data Science, LLC, USA to develop the INDP for Mali, with the following specific objectives:

- Identify the government entities and national action holders designated for the National Inventory of Dangerous Pathogens;
- Identify dangerous pathogens stored in Mali;
- Develop a comprehensive database of dangerous pathogens; and
- Establish a framework for regular updating and maintenance of the database.

1.2 Approach and methodology

I engaged in desk research, created a comprehensive manual for installing WAMPserver, collaborated with the INSP's IT Manager to successfully set up the server, visited various laboratories, facilitated a workshop to raise stakeholders' awareness, provided training sessions for lab technicians, authored a detailed guide for data entry into the MySQL database on WAMPserver, instructed the INSP's Data Manager and Biosecurity Officer on efficient data entry procedures, and personally inputted data into the MySQL database.

1.3 Limitations

The scope of the investigation was restricted by two issues:

1. *Visited only few laboratories.* Due to time constraints and other challenges, I was only able to visit only few laboratories based in Bamako.

2. *Not all stakeholders invited came to awareness workshop*. Some stakeholders outside of health were not represented in the workshop.

1.4 Structure of the report

The report is organized into the following sections:

1. Activities Conducted in the USA.
2. Visits to INSP, REDISSE III, and Laboratories.
3. Installation of WAMPServer.
4. Visit to national and private reference laboratories in Bamako.
5. Stakeholders' Awareness Workshop.
6. Training of Laboratory Technicians on Data Collection Tools.
7. National Inventory of Dangerous Pathogens and Toxins in Mali.
8. Recommendations.

2 Activities Conducted in the USA

In preparation of the forthcoming National Inventory of Dangerous Pathogens and Toxins project in Mali, Dr. Stephen Obol OPIYO (Consultant) undertook a series of strategic activities aimed at laying a robust foundation for its successful implementation. This section summarizes the Consultant's engagements, including virtual consultation meetings, coordination sessions with INSP staff, and IT planning and preparation efforts conducted in the USA.

2.1 Virtual Consultation Meeting - February 13, 2024

The Consultant commenced preparations by convening a virtual consultation meeting on February 13, 2024, gathering INSP staff under the guidance of Ms. Kadiatou DAO. During this session, the objectives, scope, and essential activities of the project were delineated. The Consultant provided invaluable information into stakeholder identification, laboratory selection, and contingency planning, with a specific focus on utilizing the WAMPserver as a backup database. WAMP stands for Windows, Apache, MySQL, and PHP, it is a software stack for the Windows operating system. Through transparent communication and planning, the Consultant ensured alignment among all parties, laying the groundwork for seamless collaboration in Mali.

2.2 Coordination Meetings - February 15, 2024

Subsequently, the consultant engaged in coordination meetings with key stakeholders, including Dr. Seydou GOITA, coordinator of the REDISSE III project, on February 15, 2024. These discussions centered around programmatic adjustments, funding availability, and challenges related to database software. The Consultant proactively proposed alternative solutions, such as leveraging the WAMPserver, to overcome challenges and ensure project continuity. Additionally, he communicated the revised project schedule, facilitating informed decision-making and recalibration of plans among stakeholders.

2.3 IT Planning and Preparation - February 22, 2024

The consultant further spearheaded a virtual meeting on February 22, 2024, with the INSP IT manager and data manager, focusing on crucial aspects pertinent to the project. This session served as a platform to share updates, delineate actionable items, and emphasize the significance of the WAMPserver within the project framework. He provided detailed

instructions for its installation upon his arrival in Mali, underscoring the importance of updates and revisions to the inventory for optimal project progression.

2.4 Conclusion of the preparation in the USA

In conclusion, the consultant’s preparatory activities in the USA laid a solid foundation for the National Inventory of Dangerous Pathogens and Toxins project in Mali. Through strategic planning, transparent communication, and adept problem-solving, he ensured seamless collaboration among stakeholders and facilitated the progression of the project towards its objectives. As he prepared to embark on the next phase of the project in Mali, the groundwork established during his engagements in the USA set the stage for a successful implementation and meaningful impact in Mali's public health sector.

3 Visits to INSP, REDISSE III, and INSP Laboratories

3.1 Engagement with INSP staff

The consultant commenced the visit with an introductory meeting at the office of Dr. Souleymane COULIBALY, where effective communication was facilitated using Google Translator. This initiative proved vital in overcoming language barriers and enhancing interactions throughout the day. Discussions were held with Dr. COULIBALY, Ms. Wadia KARAMBE, and Mr. Aburbakah DIARRA, wherein the day's schedule was outlined and fruitful exchanges took place regarding biosafety and biosecurity measures. The installation of Google Translator not only eased communication but also contributed to a productive working environment. Subsequently, a visit with the Director General of INSP, Dr. Ibrahima GUINDO, further solidified the commitment to the mission, with an emphasis on conducting a national inventory of dangerous pathogens. The supportive stance of Dr. GUINDO and his team members set a positive tone for future collaboration and initiatives aimed at enhancing public health in Mali.

3.2 Meeting with REDISSE III Project Coordinator

The consultancy visit included an introductory meeting with the REDISSE III Coordinator, Dr. GOITA, where the consultant was accompanied by a delegation from INSP. DR. GOITA stressed the importance of delivering high-quality work and emphasized the need for comprehensive documentation to ensure project sustainability. The consultant assured Dr. GOITA of his commitment to providing valuable resources and pledged to deliver materials.

3.3 Conclusion of the Introductory meetings

The consultancy introductory meetings visit in Mali was characterized by productive engagements with key stakeholders, including INSP leadership and the REDISSE III Coordinator. Effective communication, facilitated by tools like Google Translator, proved invaluable in overcoming language barriers and fostering a conducive working environment. The commitment demonstrated by institutional leaders and the consultant's pledge to deliver quality work underscored a shared vision for advancing biosafety, biosecurity, and surveillance initiatives in Mali. Moving forward, continued collaboration and concerted efforts will be crucial in achieving the objectives outlined during the visit and ensuring sustained progress in public health endeavours within the country.

3.4 Haematology Laboratory

During the visit to the Hematology Laboratory, led by Ms. Bintou Deme, the emphasis was on a patient-centric approach to sample collection and testing. Ms. Deme outlined the meticulous procedures employed in routine hematology tests, ensuring accurate and efficient diagnostic results. The laboratory's commitment to data security was evident through its systematic storage of test results in a secure database, accessible only through password-protected systems. This focus on safeguarding sensitive information aligns perfectly with the

overarching goals of the laboratory visit, which aimed to understand not only the sample collection process but also the measures taken to ensure the integrity and confidentiality of the data obtained.

3.5 Toxicology and Biochemistry Laboratory

Under the guidance of Mr. Moumine Diamoutene, the Toxicology and Biochemistry Laboratory showcased a collaborative approach to sample processing, closely integrated with the Haematology Laboratory. Through meticulous testing procedures, valuable diagnostic insights were generated, contributing to the overall diagnostic process. Similar to the Haematology Laboratory, stringent measures were in place to securely store test results, with restricted access protocols implemented to maintain confidentiality. This concerted effort in data management underscored the laboratory's commitment to ensuring the accuracy and privacy of sensitive information.

3.6 Mycobacteriology Laboratory (LNR – TB-lab)

Directed by Dr. Seydou ARAMA, the Mycobacteriology Laboratory emerged as a pivotal player in the health pyramid, receiving samples from various health centers and implementing strict protocols for safe handling. With a focus on timely diagnostics, cultures were meticulously stored to facilitate comprehensive procedures. The use of specialized healthcare software exemplified the laboratory's commitment to technological advancements in data management, complemented by robust security measures, including password authentication. Given its work with dangerous pathogens, the laboratory maintained rigorous safety protocols to protect both staff and public health, showcasing a dedication to both scientific excellence and public safety.

3.7 Bacteriology Laboratory

Accompanied by Mr. Brehima ZERBO and Mr. Adrien SIDIBE, the Bacteriology Laboratory played a vital role in processing samples from across the nation, storing them until quality control checks were conducted. Both hard copies and electronic files were maintained for data management, with access restricted to authorized personnel only. Moreover, the regular sharing of data with health authorities and international organizations highlighted the laboratory's commitment to transparency and collaboration in public health efforts.

3.8 Serology Laboratory

Under the guidance of Dr. Issa Cissé, the Serology Laboratory demonstrated its critical function in protecting public health through the analysis of samples from various sources, including during epidemics. Utilizing sophisticated software for data management, the laboratory ensured timely submissions and reporting to health authorities. Adherence to stringent safety protocols further emphasized the laboratory's dedication to staff and public safety, reflecting a comprehensive approach to handling potentially hazardous pathogens.

3.9 Molecular Biology Laboratory

Led by Mr. Demba Koita and Mr. Lassina Traoré, the Molecular Biology Laboratory showcased a well-organized workflow for handling samples, incorporating various molecular techniques to ensure accuracy. Despite lacking bioinformatics expertise and infrastructure, the laboratory's dedication to enhancing data analysis capabilities was evident through

recommendations for integration. The proposed addition of bioinformatics would not only improve the efficiency and accuracy of data analysis but also strengthen the laboratory's research capabilities in molecular biology, contributing to advancements in public health research and diagnostics.

3.10 Conclusion of the Laboratories visits at INSP

Overall, the visit to the INSP laboratories provided valuable information into the intricate processes involved in sample collection, testing, and data management within each department. Through guided tours and discussions with knowledgeable staff members, a clear picture emerged of the laboratories' commitment to security of data. Each laboratory showcased meticulous procedures and protocols aimed at safeguarding public health while ensuring the security of pathogens data.

3.10.1 Lessons Learned

One of the key lessons learned from the visit was the importance of collaboration and integration among different laboratory departments. The seamless coordination observed between laboratories such as Haematology, Toxicology and Biochemistry, and Molecular Biology highlighted the efficiency gained through shared resources and expertise. Additionally, the emphasis on stringent safety protocols underscored the critical need to prioritize staff and public safety, especially when handling dangerous pathogens.

3.10.2 Recommendations for Improvement

While the laboratories demonstrated commendable practices, there are areas for improvement to further enhance their capabilities. One such recommendation is the integration of bioinformatics expertise and infrastructure within the Molecular Biology Laboratory. By investing in bioinformatics, the laboratory can streamline data analysis processes, improve the interpretation of sequence data, and leverage advanced computing tools for enhanced research capabilities. Additionally, ongoing training programs and collaborations with experts in the field can help build internal expertise and strengthen the laboratory's capacity in bioinformatics.

Furthermore, there is potential for increased collaboration and data sharing not only within the laboratories but also with external stakeholders, including other research institutions and international organizations. By fostering partnerships and promoting data exchange, the laboratories can contribute to a more comprehensive understanding of infectious diseases and facilitate global efforts in disease surveillance, prevention, and control.

In conclusion, the visit to the INSP laboratories provided valuable information into their operations and highlighted opportunities for growth and improvement. By implementing recommendations such as integrating bioinformatics expertise and fostering collaboration, the laboratories can further enhance their contributions to public health in Mali and beyond.

4 Installation of WAMPServer

4.1 Server Installation Process

In a virtual meeting between the INSP IT Specialist, Data Manager, and a consultant from the United States, it was decided to install WAMPServer on a Dell Inspiron computer running Windows 11. This server setup includes Windows, Apache, MySQL/MariaDB, and PHP components. The installation process adhered to industry standards to seamlessly integrate server components. Additionally, rigorous security measures were implemented to safeguard the database. The IT Manager successfully downloaded WAMPServer and completed the installation process with the assistance of the consultant. The Dell Inspiron's specifications, including an Intel i7 Core processor, 8 GB RAM, and a 500 GB hard disk, provided ample resources for hosting the server.

4.2 Security Measures Implemented

4.2.1 Disconnecting from the Internet

To minimize external threats and unauthorized access, the computer hosting the database remains disconnected from the Internet. This isolation strategy enhances security by reducing the attack surface.

4.2.2 Password Protection

Access to both the computer and database is password protected. Only authorized personnel, including the IT manager, data manager, and IT and biosecurity manager, possess the necessary credentials. This measure ensures access control and prevents unauthorized entry.

4.2.3 Regular Database Backups

A robust backup strategy is in place to maintain data integrity and facilitate recovery in case of unforeseen events. The database undergoes regular backups, with the backup data securely stored by the biosafety and biosecurity Manager. This measure ensures resilience against data loss and system failures.

4.2.4 Collaborative Security Maintenance

To ensure continued security, the IT Department, Data Manager, and Biosafety and Biosecurity Manager collaborate closely. Their responsibilities include monitoring, updating security protocols, and addressing potential vulnerabilities. This collaborative effort ensures ongoing protection of the National Inventory of Dangerous Pathogens data.

4.3 Conclusion on WAMPServer installation

The successful installation of WAMPServer and the implementation of comprehensive security measures represent a significant milestone in safeguarding dangerous pathogens and toxins data in Mali. By adhering to industry standards and collaborating across departments, the

organization has taken proactive steps to protect the integrity and confidentiality of its database. Continued vigilance and collaboration will be essential to maintaining a secure environment and mitigating emerging threats.

5 Visit to national and private reference laboratories in Bamako

The laboratory visits took place on March 5 and 6, with questions specifically tailored to meet the objectives of the INPD project. Emphasis was placed on various aspects including the sample collection process, encompassing methodologies, protocols and shelf life. Discussions also covered data collection approaches and storage systems, with a particular focus on access control measures. These measures have deepened the criteria for authorizing access to data and the effectiveness of security protocols in protecting sensitive information. Refer to Table 1 for the laboratories visited.

Table 2: List of reference laboratories visited in Bamako

Organizations	Date of vists
1. University Clinical Research Center of Mali (UCRC)	5 March 2024
2. Charles Mérieux Infectiology Center (CICM)	
3. The Applied Molecular Biology Laboratory (LBMA)	5 March 2024
4. The Institute of Rural Economy (IER) Sotuba Biotechnology Laboratory	6 March 2024
5. Central Veterinary Laboratory (LCV)	6 March 2024
6. Mali Hospital	6 March 2024

5.1 University Clinical Research Center of Mali (UCRC)

The University Clinical Research Center of Mali (UCRC) stands as a pivotal hub for core research activities, boasting essential facilities ranging from scientific laboratories to specialized diagnostic laboratories and pharmacies. Its success lies in its stringent safety protocols, strictly regulating access to the BSL-3 laboratory and ensuring regular safety certifications. Collaborations with esteemed institutions like the Atlanta CDC and NIH underscore UCRC's commitment to international standards. However, challenges persist, including the need for continuous training programs to keep staff updated on evolving security measures and technologies. Additionally, while UCRC has maintained an impeccable safety record, the consistent application of safety protocols remains crucial in the face of emerging infectious diseases.

5.2 Charles Mérieux Infectiology Center (CICM)

The Charles Mérieux Infectiology Center (CICM) shines as a beacon of research and services in infectious diseases, boasting ISO 15189 accreditation and a commitment to diagnostic excellence. Its success lies in its partnerships with renowned institutions and its rigorous safety protocols, despite lacking formal accident protocols. Challenges arise in the form of outsourced bioinformatics capabilities and the need to strengthen internal capacities for data analysis. Improvements such as developing accident protocols and in-house bioinformatics facilities could enhance emergency preparedness and research efficiency, consolidating CICM's leading position in infectious disease management.

5.3 Applied Molecular Biology Laboratory (LBMA)

The Applied Molecular Biology Laboratory (LBMA) excels in diagnostics, biotechnology, entomology, and environmental studies, addressing parasitic pathogens and collaborating with esteemed entities like INSP and CDC Atlanta. Its success is evidenced by its annual biosafety training and waste disposal methods. However, challenges persist in sample tracking protocols and bioinformatics capabilities. Implementing sample tracking systems and enhancing in-house bioinformatics expertise could bolster efficiency and data security, ensuring continued excellence in research and collaboration.

5.4 Institute of Rural Economy (IER) Sotuba Biotechnology Laboratory

The Institute of Rural Economy (IER) Sotuba Biotechnology Laboratory plays a pivotal role in agricultural innovation, with extensive research efforts focused on genetic diversity and stress monitoring. Its successes include collaborations with national and international partners, contributing to agricultural progress. However, challenges such as inadequate waste disposal mechanisms and data management systems hinder efficiency. Improvements like outsourcing waste disposal and implementing data management systems could enhance sustainability practices and research effectiveness, furthering IER's contributions to agricultural development.

5.5 Central Veterinary Laboratory (LCV)

The Central Veterinary Laboratory (LCV) stands as a central institution dedicated to veterinary medicine, boasting state-of-the-art laboratories and a commendable safety record. Successes include its diagnostic and research functions, as well as its role in vaccine production and food safety monitoring. Challenges include the lack of a central bioinformatics facility and the need for continued investment in infrastructure. Strengthening bioinformatics capabilities and infrastructure could enhance research efficiency and collaboration, further solidifying LCV's contributions to animal and public health.

5.6 Mali Hospital

Mali Hospital serves as a leading national institution, offering a wide range of medical services and excelling in diagnostic excellence. Successes include its commitment to biosafety protocols and involvement in genetic sequencing activities. Challenges arise from the reliance on external partners for bioinformatics analysis and the need to establish in-house capabilities. Investing in in-house bioinformatics facilities and staff training could enhance research capabilities and preparedness against emerging health threats, ensuring continued excellence in healthcare provision.

5.7 Conclusion from national and private reference laboratories visits

From the visits to various research institutions and hospitals in Mali, several key lessons have emerged. Firstly, the critical importance of strict safety protocols and robust bioinformatics capabilities in managing pathogens and ensuring biosafety and biosecurity cannot be overstated. Each institution showcased a commitment to safety measures, but gaps in accident protocols and bioinformatics capacity were identified. These visits underscored the

necessity of continuous training programs to keep staff informed of evolving security measures and technologies, as well as the importance of investing in internal bioinformatics expertise to reduce reliance on external partners. Secondly, collaboration, both locally and internationally, was evident across all institutions, demonstrating the significance of collective efforts in addressing public health challenges. Leveraging partnerships with esteemed institutions and fostering collaborations for mutual benefit emerged as essential strategies. However, there remains room for improvement in maximizing the potential of these collaborations, particularly in enhancing data sharing and expertise exchange to strengthen research capabilities and response readiness. To improve, institutions should prioritize the development and implementation of formal accident protocols to strengthen emergency preparedness and response. Investing in in-house bioinformatics facilities and staff training programs would enhance research efficiency and reduce dependencies on external partners for data analysis.

6 Raising Stakeholder Awareness Workshop

6.1 The awareness and training workshop

A stakeholder awareness and training workshop took place in Bamako on March 7, 2024, focusing on understanding dangerous pathogens and threats to public health, as well as promoting stakeholder collaboration. The workshop commenced with speeches emphasizing the importance of stakeholders and collaborative efforts in mitigating risks associated with dangerous pathogens.

The workshop had two main objectives. Firstly, it aimed to address Understanding Dangerous Pathogens and Threats to Public Health. This objective covered identification, risks, impacts, and prevention strategies related to dangerous pathogens. Topics included various types of pathogens, associated risks (such as infectious diseases and bioterrorism), prevention strategies (vaccination, hygiene, surveillance), and the economic, health, and environmental impacts of epidemics.

Secondly, the workshop focused on Stakeholder Awareness and Collaboration. This objective emphasized the importance of stakeholder involvement and collaborative approaches in combating dangerous pathogens. It included discussions on the National Inventory of Dangerous Pathogens and Toxins (INPD), focusing on its phases (identification, preparation, implementation, maintenance) and operational procedures.

The INPD process involved several phases. In the identification phase, relevant stakeholders were determined, priority pathogens were identified, and awareness-raising actions were initiated. The preparation phase focused on selecting database elements, identifying institutions storing pathogens, and conducting awareness campaigns. During the implementation phase, database software was determined, data was collected from institutions, and it was securely stored in a central database. Finally, the maintenance and evaluation phase involved analyzing data, updating the database periodically, and ensuring ongoing effectiveness.

Stakeholder awareness and collaboration are essential components in effectively addressing health crises and combating dangerous pathogens. Government ministries play a central role in this endeavour, with key departments such as Health and Social Development, Agriculture, Livestock and Fisheries, and Environment, among others, responsible for critical functions like disease surveillance, health system management, and environmental health. Collaborating with international organizations such as the World Health Organization (WHO) ensures coherent responses to health crises, strengthens disease surveillance, and enhances health system capabilities.

Coordination and mobilization of resources are emphasized, particularly in emergency scenarios, underscoring the need for ministries and organizations to work together for efficient resource utilization and timely assistance. Research and education initiatives are deemed crucial, with ministries responsible for Education and Scientific Research identified as pivotal players in promoting literacy, public health awareness, and research aimed at addressing emerging threats.

Protecting vulnerable populations is paramount, with ministries dedicated to the advancement of women and children recognized for their role in initiatives focused on vaccination, education, and access to healthcare. In combating dangerous pathogens, collaborative approaches involving diverse sectors and stakeholders are imperative. Inter-ministerial collaboration ensures comprehensive responses covering health, environment, security, and education, while partnerships with international organizations and regional cooperation bolster surveillance, response, and capacity-building efforts.

Engagement with civil society and the private sector empowers communities, strengthens health systems, and improves resource distribution. Research and innovation partnerships inform robust response strategies, while legal and ethical frameworks ensure transparent and rights-respecting disease control measures. Collaboration between military and public health sectors enhances national security and bioterrorism preparedness.

Diplomatic engagement fosters global cooperation against health threats, while support from ministries overseeing infrastructure guarantees access to essential services during outbreaks. Inclusive healthcare strategies prioritize vulnerable groups, with a focus on women and children, and supply chain resilience, facilitated by the Ministry of Industry and Commerce, ensures effective distribution of medical supplies during pathogen epidemics. Overall, stakeholder collaboration across various sectors and levels is vital in tackling health challenges and safeguarding public well-being.

6.2 Questions and discussion during the workshop

6.2.1 Handling of Ricin Toxin

The workshop initiated discussions surrounding the safe handling of Ricin toxin, emphasizing the critical importance of implementing robust biosafety and biosecurity protocols. Various strategies were explored to mitigate potential risks associated with Ricin, ensuring the safety of personnel and preventing accidental exposure. Participants engaged in detailed conversations regarding best practices for containment, disposal, and personnel protection measures to effectively manage the hazards posed by Ricin toxin within laboratory settings or other relevant environments.

6.2.2 Database Security Measures

A significant portion of the workshop was dedicated to addressing concerns related to database security measures. Participants received assurances from experts regarding the implementation of comprehensive security protocols, which included offline access, password protection, regular updates, and collaborative efforts between IT personnel and relevant stakeholders. Discussions underscored the critical role of robust database security in safeguarding sensitive information related to dangerous pathogens and toxins, ensuring confidentiality, integrity, and accessibility of vital data.

6.2.3 Relevance of Pathogens Lists

During the workshop, participants raised pertinent questions regarding the relevance of pathogen lists, particularly those derived from the USA, to the biosecurity landscape of Mali. The need to tailor and revise these lists to align with Mali's specific biosecurity threats was

highlighted as a crucial step towards enhancing preparedness and response capabilities. Experts led discussions on the process of evaluating and updating pathogen lists to accurately reflect the unique context and priorities of Mali, thereby ensuring a more effective response to biosecurity risks.

6.2.4 Pathogen Risk Groups Determination

Plans were outlined during the workshop to address the process of determining pathogen risk groups in Mali. Experts proposed engaging in comprehensive discussions and training sessions to assess and classify pathogens based on their inherent risks. The approach involved leveraging frameworks provided by the World Health Organization (WHO) and adapting them to suit the specific context and needs of Mali. By establishing clear risk classifications, stakeholders aimed to enhance decision-making processes and allocate resources more effectively to mitigate biosecurity threats.

6.2.5 Military Involvement During Epidemics

Discussions during the workshop delved into the potential role of the military in providing logistical support during epidemics caused by dangerous pathogens. Participants explored collaborative approaches between the military and health ministries to address biosecurity threats effectively. Experts emphasized the importance of leveraging military infrastructure, resources, and expertise to facilitate the transportation of supplies, establishment of medical facilities, and coordination of emergency response efforts alongside relevant government ministries. This collaborative framework aimed to enhance the overall preparedness and response capabilities in the event of biosecurity emergencies.

6.3 Evaluation of the workshop

The evaluation of the workshop based on participant responses indicates an overwhelmingly positive reception across all assessed areas. The workshop's relevance to participants' work was unanimously affirmed, with 60% strongly agreeing and 40% totally agreeing, demonstrating a clear alignment between the content covered and professional needs. Similarly, participants found the workshop material both interesting and easy to follow, with 61% strongly agreeing and 33% agreeing. The facilitator's presentation style was highly praised, with 80% of respondents strongly agreeing that it enhanced their learning experience. Additionally, the workshop atmosphere was universally perceived as pleasant, and the logistics were well managed according to 100% of respondents. Moreover, the duration of the workshop was viewed favourably by 90% of participants, indicating high satisfaction with the event's organization and timing.

Furthermore, the workshop significantly improved participants' understanding of the topics covered. For instance, after the workshop, there was a notable increase in understanding across all topics, including "Introduction to Dangerous Pathogens," "National Inventory of Dangerous Pathogens and Toxins," "Importance of stakeholder involvement," and "Collaborative approaches to combat threats from dangerous pathogens and toxins." These improvements were particularly striking, with shifts towards higher levels of understanding and a complete absence of very low understanding ratings after the workshop. Overall, the workshop received unanimous praise for its effectiveness in meeting participants' needs,

fostering a conducive learning environment, and enhancing understanding of key concepts, highlighting its success in achieving its objectives and creating substantial value for attendees.

6.4 Conclusion from the stakeholders' workshop

6.4.1 Importance of Collaboration

The workshop emphasized the critical role of stakeholder collaboration in addressing biosecurity threats. This highlights the importance of fostering partnerships across sectors and levels of governance to effectively combat dangerous pathogens.

6.4.2 Need for Comprehensive Preparedness

Discussions surrounding handling Ricin toxin and military involvement during epidemics underscored the necessity of comprehensive preparedness plans. This includes not only scientific protocols but also logistical and organizational strategies involving various stakeholders.

6.4.3 Database Security

Ensuring robust database security measures is vital to safeguard sensitive information related to dangerous pathogens. Participants recognized the importance of offline access, password protection, and regular updates to maintain the confidentiality and integrity of data.

6.4.4 Tailoring Responses to Local Contexts

The relevance of pathogen lists, and risk group determinations was highlighted, emphasizing the need to tailor responses to the specific biosecurity landscape of Mali. This involves evaluating and updating protocols and lists to align with local priorities and threats.

6.4.5 Effective Communication and Training

The positive evaluation of the workshop indicates that effective communication and training methods were employed, enhancing participants' understanding of key concepts. This underscores the importance of clear, engaging presentations and interactive discussions in knowledge dissemination.

7 Training of Laboratory Technicians on Data Collection Tools

The training of laboratory technicians regarding dangerous pathogens commenced similarly to a previous stakeholder awareness workshop. It commenced with a consultant's presentation, outlining the training program spanning five days, with the initial focus on general pathogen information for two days and the subsequent three days dedicated to tool. The Head of the Department of Quality, Safety, and Biological Security, Hygiene, and Pharmacovigilance expressed gratitude to participants and recognized the organizing team's efforts, emphasizing the presence of an expert. Subsequently, an administrative and human resources manager, representing the INSP director, delivered a warm welcome speech. The ceremony included participant introductions, administrative matters review, observations, adoption of the agenda, and concluded with group photographs.

7.1 Presentations

The training encompassed three key models: Identification of dangerous pathogens and toxins; Ethical and legal considerations; and Inventory Tool for Hazardous Pathogens and Toxins.

7.2 Model 1: Identification of dangerous pathogens and toxins

Under this model, the following topics were covered: Introduction to dangerous pathogens and associated risks; Existing knowledge about dangerous pathogens; Inventory frameworks for dangerous pathogens and toxins; Recognition and understanding of various dangerous pathogens; and Overview of the latest developments and research in the field of dangerous pathogens.

7.2.1 Introduction to Dangerous Pathogens and Associated Risks

The consultant discussed with the laboratory technicians the risks associated with dangerous pathogens, emphasizing the need for collaborative efforts to prevent and manage outbreaks. Lessons learned from past pandemics, including COVID-19, were highlighted, stressing the importance of early detection, rapid action, and international cooperation.

7.2.2 Existing Knowledge About Dangerous Pathogens

The consultant discussed the challenges posed by emerging infectious diseases, emphasizing the interconnectedness of human, animal, plant, and environmental health. Workshop participants emphasized the importance of global surveillance networks, early detection, and international cooperation to mitigate the impact of pandemics. Strategies to improve global preparedness were identified, including investing in technology, strengthening collaboration, and creating emergency response plans.

7.2.3 Dangerous Pathogens and Toxins Inventory Frameworks

International organizations like WHO and Africa CDC, along with regional and national entities, were recognized for their roles in mitigating risks associated with hazardous materials.

Emphasis was placed on risk assessment, secure storage, and collaboration to ensure effective monitoring and compliance.

7.2.4 Recognition and Understanding of Various Dangerous Pathogens

Genetic and biochemical analysis techniques were discussed for identifying and tracking pathogens. Surveillance strategies and diagnostic tools were highlighted for their role in early detection and intervention. Community engagement, international cooperation, and research efforts were emphasized for effective response.

7.2.5 Overview of the Latest Developments and Research

Continuous improvement in response to emerging threats was stressed, with a focus on genomic surveillance, CRISPR-based diagnostics, and breakthroughs in imaging and proteomics. Advances in vaccination technologies, preventive measures, and digital surveillance systems were highlighted for combating current and future threats effectively.

7.2.6 Summary of Model 1

Overall, the model emphasizes collaboration, early detection, and continuous improvement in response strategies to combat the ever evolving threat of dangerous pathogens and toxins.

7.3 Model 2: Legal and ethical considerations

Managing dangerous pathogens and toxins demands a rigorous adherence to legal and ethical principles to safeguard individuals, communities, and the environment. These principles are crucial for preventing accidental releases and deliberate misuse, while also advancing responsible research and public health initiatives. Key considerations include compliance with regulations, upholding biosafety and biosecurity standards, promoting international collaboration, and facilitating the exchange of data. By prioritizing these factors, organizations can effectively manage the risks associated with dangerous pathogens while promoting the well-being of society. Key aspects highlighted in the training include Legal Compliance; Ethical Considerations; and Environmental Impact Assessment.

7.3.1 Legal Compliance

Emphasis is placed on adhering to regulatory frameworks governing pathogen research to avoid legal repercussions. This involves understanding and implementing protocols for risk assessment, continuous monitoring, and adapting to evolving standards. Proper laboratory design, personal protective equipment (PPE), access controls, and incident response protocols are crucial to prevent accidental releases and unauthorized access.

7.3.2 Ethical Considerations

Ethical dimensions of pathogen research, particularly in international collaboration and information sharing, are underscored. Clear guidelines are necessary to promote transparency, protect intellectual property, and address dual-use concerns. Community engagement and obtaining informed consent are essential to uphold research integrity and foster trust among stakeholders.

7.3.3 Environmental Impact Assessment

Recognizing the potential environmental risks associated with pathogen-related activities, training emphasizes the importance of compliance with regulations, obtaining permits, and conducting environmental impact assessments. Periodic review and updating of protocols are necessary to minimize adverse impacts on ecosystems, biodiversity, and human health.

7.3.4 Summary of Model 2

Model 2 emphasizes how legal, ethical, and environmental considerations are interconnected in the effective management of pathogens. It underscores the necessity of proactive measures and continuous vigilance to mitigate risks and uphold responsible research practices.

7.4 Module 3: Hazardous Pathogens and Toxins Inventory Tool

Module 3 played a pivotal role in the training session, focusing on practical engagement to refine the Dangerous Pathogens and Toxins Data Collection Tool for effective use in gathering data on dangerous pathogens and toxins in Mali. Participants actively collaborated in group settings, working towards enhancing the tool's efficiency. Additionally, this module provided comprehensive coverage of various data collection techniques essential for the task at hand.

7.4.1 Tool for collecting data on Pathogens and Toxins Data Collection

The Tool was developed based on information from publications (2, 3). The tool was improved by working with participants during the training workshop. The participants were divided into three groups. The working groups were tasked with categorizing various pathogens based on established criteria from WHO (4), the British Government (5), and adapted Canadian Guidelines (6), tailored to suit the context of Mali. These criteria included factors such as mode of transmission, host characteristics, presence in reservoirs, vectors of transmission, infectious potential, risk of spreading to the population, availability of vaccines or treatments, and potential societal, economic, or public health impacts. Furthermore, it is imperative to rely on credible sources of information about dangerous pathogens and toxins (7 - 14).

To validate the results, each group presented their classifications in a plenary session. Participants reviewed and discussed the outcomes, with the majority within each group generally in agreement with their respective classifications. Any discrepancies were thoroughly discussed. The process continued the following day, with the same set of ten pathogens provided to all three groups. Following the exercise, each group shared their findings, revealing minimal disparities in the classifications despite their independent evaluations of the pathogens. The outcome of this collaborative effort was the development of a comprehensive data collection tool for dangerous pathogens and toxins specifically tailored for Mali's context.

7.4.2 Data collection techniques

Data collection techniques covered included Observation, Surveys, and Questionnaires and Schedules.

- **Observation:** Observation involves directly monitoring the behaviour and dynamics of dangerous pathogens and toxins in real-time. Researchers use this method to track the movement, proliferation, and distribution patterns of these entities. One significant advantage of observation is its ability to provide immediate insights into emergent situations, enabling timely interventions to mitigate risks to public health and the environment. Additionally, observational studies are typically non-invasive, as they do not require direct contact with study subjects or environmental samples, minimizing the risk of contamination or bias. However, the interpretation of observational data may be subjective, influenced by the observer's perspective and expertise. Furthermore, observational studies may have a limited scope, capturing only surface-level behaviors or manifestations of pathogens and toxins, without delving into underlying mechanisms or causative factors. Conducting observational research can also be resource-intensive, requiring significant time, personnel, and logistical resources, especially for long-term monitoring studies or observations in remote locations.

- **Surveys:** Surveys are employed to collect large-scale data on the prevalence, distribution, and associated risk factors of dangerous pathogens and toxins. Researchers use standardized questionnaires to systematically gather information from populations or environmental samples. One major advantage of surveys is their ability to yield comprehensive insights into population-level trends and patterns. They allow for the collection of quantitative data on exposure levels, symptoms, and other relevant variables, facilitating rigorous statistical analysis and hypothesis testing. However, surveys are susceptible to response bias, as participants may provide inaccurate or inconsistent responses due to factors like social desirability bias or recall bias. Additionally, surveys typically focus on predefined questions or variables, limiting the depth of information collected compared to qualitative methods like interviews. Designing, administering, and analyzing surveys can also be resource-intensive, particularly for large-scale studies or surveys conducted across diverse populations.

- **Interviews:** Interviews involve conducting structured or semi-structured discussions with individuals affected by dangerous pathogens and toxins, as well as healthcare professionals or environmental experts. Researchers use interviews to gain in-depth qualitative insights into the socio-economic, cultural, and behavioral determinants influencing the spread and impact of these entities. One advantage of interviews is their ability to capture nuanced perspectives and experiences, enriching our understanding of the human dimensions of infectious disease outbreaks and environmental contamination incidents. Interviews also foster rapport and trust between researchers and participants, encouraging open and candid dialogue, particularly in sensitive or stigmatized topics. However, conducting interviews can be time-consuming, requiring extensive planning and coordination, especially for in-person or semi-structured interviews. Additionally, interview data may be influenced by interviewer bias or interpretation, affecting the reliability and validity of the findings. Furthermore, the qualitative nature of interview data may limit its generalizability to broader populations or contexts, particularly if the sample size is small or non-representative.

- **Questionnaires and Schedules:** Questionnaires and schedules are used to collect data from large populations or sample sizes in a cost-effective manner. Researchers

administer standardized questionnaires to study participants or field enumerators to gather information on exposure history, risk behaviors, and preventive measures related to dangerous pathogens and toxins. One advantage of questionnaires and schedules is their cost-effectiveness, as they minimize the need for extensive resources or personnel. They also offer anonymity to respondents, who may feel more comfortable providing honest and candid responses to sensitive questions in written formats. However, the quality of responses to questionnaires may be affected by factors such as respondent fatigue, misunderstanding of questions, or incomplete responses, compromising data quality. Additionally, questionnaires lack the interactive nature of interviews, potentially limiting the depth of information collected and precluding clarification of responses. Moreover, responses to questionnaires may be influenced by self-report bias, wherein participants may over-report or under-report certain behaviors or experiences, leading to inaccuracies in the data.

7.4.3 Summary of Model 3

The outcome of Module 3 training was the successful refinement and development of a Dangerous Pathogens and Toxins data collection Tool specifically tailored for use in Mali. Through collaborative group work and discussions, participants categorized various pathogens based on established criteria, resulting in a comprehensive classification system. This tool was refined through iterative discussions and presentations, ensuring alignment with the context and needs of Mali. Additionally, the module covered various data collection techniques including observation, surveys, interviews, and questionnaires, providing participants with a diverse toolkit for gathering essential data in their labs. Overall, Module 3 facilitated active engagement and practical skill-building, empowering participants with the knowledge and tools necessary to effectively collect data and mitigate risks posed by dangerous pathogens and toxins in Mali.

7.5 Pre-Test and Post-Test

The effectiveness of a workshop aimed at enhancing participants' understanding of specific topics was assessed through pre-test and post-test evaluations. Prior to the workshop, twenty-three participants completed a pre-test, providing a baseline measure of their comprehension. Following the workshop, which covered the topics assessed in the pre-test, twenty two participants underwent a post-test evaluation. The results revealed a notable improvement in participant performance from the pre-test to the post-test. This enhancement suggests that the workshop successfully achieved its objectives of enhancing participants' understanding of the covered topics. The positive shift in performance underscores the value of such workshops in facilitating knowledge acquisition and retention among participants.

7.6 Validation of the Training Workshop

The evaluation of the training workshop overwhelmingly demonstrates its effectiveness and success in meeting participants' needs and expectations. Across various metrics including relevance to participants' work, the quality of materials, the facilitator's presentation style, logistical management, and overall satisfaction, the feedback consistently indicates high levels of approval and appreciation. Notably, participants unanimously agreed that the facilitator's approach enhanced their learning experience, and the majority expressed satisfaction with the workshop's duration and logistics management. Furthermore, the evaluation reveals

significant improvements in participants' understanding of key topics such as legal and ethical considerations, disease risk classification, and the collection of dangerous pathogens and toxins in Mali. These results underscore the workshop's impact in imparting valuable knowledge and skills, validating its importance in addressing critical issues related to pathogen management and research practices.

In conclusion, the workshop evaluation affirms the success of the training program in achieving its objectives and delivering tangible value to participants. The overwhelmingly positive feedback, coupled with evident enhancements in participants' comprehension, highlights the effectiveness of the workshop in equipping individuals with essential tools and knowledge for data collection. This robust validation not only underscores the efforts invested in designing and conducting the workshop but also provides valuable insights for refining future training sessions, ensuring continued improvement in participant learning and engagement. Overall, the evaluation reflects a resounding endorsement of the workshop's significance and impact in advancing expertise and practices related to the collection and management of dangerous pathogens and toxins in Mali.

8 National Inventory of Dangerous Pathogens and Toxins in Mali

8.1 Entering data into MySQL database

Following the completion of the training workshop, some participants promptly submitted their collected data to the INSP Data Manager. Subsequently, the consultant provided comprehensive training sessions to both the data manager and the biosafety and biosecurity manager, focusing on the proficient entry of data into the MySQL database. With their newfound expertise, they meticulously and securely entered the collected data into the database.

This initiative culminated in the establishment of the **National Inventory of Dangerous Pathogens and Toxins in Mali**. The database serves as a crucial repository for vital information pertaining to dangerous pathogens and toxins within the country's borders. Every aspect of this data, including details regarding the number of dangerous pathogens and toxins identified and their respective laboratories, is handled with utmost confidentiality and discretion.

By centralizing this information within the database, Mali has taken significant strides towards bolstering its preparedness and response capabilities in the realm of public health emergencies and biosecurity threats. This comprehensive inventory not only facilitates efficient monitoring and surveillance but also enables prompt and targeted interventions, when necessary, thereby safeguarding the health and well-being of the nation's populace.

8.2 Uganda National Inventory of Dangerous Pathogens and Toxins

While several African countries have been mentioned in regard to the development of National Inventories of Dangerous Pathogens (3), to the best of current knowledge, Uganda remains the only nation to have publicly disclosed its approach (2). Thus, for illustrative purposes, I compare this project with Uganda's published methodology (See Table 2).

Table 3: Comparative Development Processes of the Inventory of Dangerous Pathogens and Toxins in Uganda and Mali.

Aspect of Development	Uganda	Mali
Government entity responsible for the INPD	Ministry of Health	Ministry of Health and Social Development
Focal point responsible for interacting with laboratories, collecting data and maintaining the database	Uganda National Council of Science and Technology (UNCST)	The National Institute of Public Health (INSP)

Select agents	Uganda used list of select agents from USA (1)	Developed a tool designed to facilitate the gathering of agents alongside laboratory technicians during training sessions.
Database (Software)	National Institute for Public Health and the Environment (RIVM) (15)	Developed locally with WAMPserver

In comparing the processes of developing National Inventory of Dangerous Pathogens and Toxins between Uganda and Mali, several similarities and differences emerge.

Government Entity Responsible for the National Infectious Disease Program (INPD)

- ***Uganda:*** Ministry of Health
- ***Mali:*** Ministry of Health and Social Development

Both countries designate their respective Ministries of Health as the primary government entity responsible for overseeing the National Infectious Disease Pathogens and Toxins (INPD). However, Mali extends its responsibilities to include social development aspects, potentially indicating a broader approach to public health.

Focal Point for Interacting with Laboratories and Data Collection

- ***Uganda***: Uganda National Council of Science and Technology (UNCST)
- ***Mali:*** The National Institute of Public Health (INSP)

Both countries have specific institutions tasked with interacting with laboratories, collecting data, and maintaining databases related to dangerous pathogens and toxins. However, while Uganda assigns this responsibility to a council focused on science and technology, Mali's responsibility lies with a dedicated public health institute.

Select Agents (pathogens and toxins)

- ***Uganda:*** Utilizes a list of select agents from the USA.
- ***Mali:*** Developed a tool to gather agents alongside laboratory technicians during training sessions.

Uganda relies on an existing list of select agents, likely from the USA, for categorizing and monitoring infectious agents. In contrast, Mali has developed its tool to facilitate the gathering of agents, potentially indicating a more localized and tailored approach to surveillance.

Database Software

- ***Uganda:*** Utilizes software from the National Institute for Public Health and the Environment (RIVM)
- ***Mali:*** Developed a local database with WAMPserver (MySQL).

Uganda utilizes software from an external institution (RIVM) for its database needs, suggesting a reliance on pre-existing technology and expertise. On the other hand, Mali has developed its database locally, potentially indicating a more self-reliant approach or specific needs that necessitate a custom solution.

In summary, both Uganda and Mali demonstrate efforts to establish and maintain INPD. While they share similarities in government oversight and data collection responsibilities, differences emerge in their approaches to select agents and database management, reflecting unique contextual factors in each country.

9 Conclusions

The activities undertaken as part of the INAPD project in Mali have been instrumental in laying a robust foundation for bolstering the country's capacity to manage and mitigate risks associated with dangerous pathogens and toxins. The preparatory activities conducted in the USA provided invaluable information, setting the stage for successful collaboration and knowledge exchange. By fostering seamless communication and problem-solving strategies, the groundwork laid during these engagements has paved the way for the effective implementation of the INAPD project in Mali's public health sector. The commitment demonstrated by all stakeholders underscores a shared vision for advancing public health initiatives and addressing emerging health threats.

Furthermore, the introductory meetings in Mali facilitated productive engagements with key stakeholders, fostering a conducive working environment characterized by effective communication and collaboration. Recommendations stemming from laboratory visits underscore the importance of continued investment in bioinformatics expertise, infrastructure, and collaboration to enhance research capabilities and data sharing. By integrating bioinformatics and strengthening partnerships with external stakeholders, Mali's laboratories can contribute to a more comprehensive understanding of dangerous pathogens and toxins and bolster global efforts in disease surveillance and prevention.

The evaluation of workshops revealed a high level of participant satisfaction and significant improvements in understanding across key topics related to dangerous pathogens and toxins. These findings underscore the effectiveness of the training programs in equipping participants with essential knowledge and skills for managing and mitigating health risks.

The successful installation of WAMPServer and the establishment of the National Inventory of Dangerous Pathogens and Toxins mark significant milestones in Mali's efforts to strengthen biosafety and biosecurity measures. By leveraging open-source technologies and fostering collaboration, Mali has established a robust framework for data management and continuous improvement in combating health threats.

Moving forward, recommendations for investment in internal bioinformatics expertise, centralized data management systems, and ongoing training underscore the importance of sustained efforts to strengthen Mali's capacity to respond to emerging health challenges effectively. By prioritizing collaboration, stakeholder engagement, and continuous improvement, Mali can further enhance its resilience against health threats from dangerous pathogens and toxins and safeguard public health and safety for years to come.

In conclusion, the activities outlined above collectively demonstrate Mali's commitment to advancing its capabilities in managing dangerous pathogens and toxins. Through strategic investments, collaborative partnerships, and ongoing training initiatives, Mali is well-positioned to address current and future health challenges effectively. The progress achieved to date reflects a shared dedication to promoting public health, enhancing biosafety, and safeguarding the well-being of Mali's population.

10 Recommendations

10.1 Invest in internal bioinformatics expertise or partnerships

Laboratories in Mali should invest in developing internal bioinformatics expertise within its research institutions or institutions establish partnerships with organizations like the INSP to enhance its capacity for data analysis and interpretation. By training staff in bioinformatics techniques and collaborating with institutions like INSP, Labs in Mali can strengthen their bioinformatics capabilities. Additionally, partnerships with other labs can be established to develop a Bioinformatics core facility, which would serve as a centralized hub for bioinformatics analysis and interpretation of pathogen data.

10.2 Implement centralized systems for data management

Laboratories in Mali should establish centralized systems to ensure data integrity, facilitate collaboration among researchers, and enhance research efficiency. This could involve the development of a centralized database or platform where researchers can securely store, access, and analyze data related to pathogens. This centralized system would streamline data management processes, promote collaboration among researchers, and ensure that data is easily accessible for analysis and decision-making.

10.3 Continue Monitoring Laboratories collecting data

Mali should enhance its Dangerous Pathogens Data Collection Tool by incorporating additional factors such as economic activities and other relevant variables. This will provide a more comprehensive understanding of the factors influencing the spread and impact of dangerous pathogens in Mali. The INSP team should monitor laboratories collecting dangerous pathogens and toxins every six months for compliance.

10.4 Outsource waste disposal and implement proper waste management protocols

Laboratories with no proper waste management system should outsource the disposal of hazardous waste generated from research activities involving dangerous pathogens to a third-party provider equipped to handle it safely and in an environmentally friendly manner, such as through incineration. Additionally, Mali should implement proper waste management protocols within research facilities to ensure compliance with environmental regulations and minimize potential hazards associated with the handling and disposal of dangerous pathogens.

10.5 Invest in staff training in biosafety and biosecurity

Laboratories in Mali should prioritize staff training in biosafety and biosecurity measures to ensure that researchers and laboratory personnel are equipped with the knowledge and skills necessary to safely handle dangerous pathogens. This training should cover topics such as proper laboratory techniques, use of personal protective equipment, and protocols for handling and storing dangerous pathogens to minimize the risk of accidental exposure or release.

10.6 Implement a comprehensive sample tracking system

Laboratories that lack sample tracking should establish a comprehensive sample tracking system using barcode technology or similar methods to ensure the accuracy, integrity, and traceability of samples throughout the testing process. This system will help researchers monitor the movement of samples from collection to analysis, reducing the risk of sample mix-ups or contamination and ensuring reliable data for inclusion in the National Inventory of Dangerous Pathogens.

10.7 Prioritize the development of formal accident protocols

Some laboratories should prioritize the development and implementation of formal accident protocols to strengthen emergency preparedness in the event of accidents or incidents involving dangerous pathogens. These protocols should outline clear procedures for responding to accidents, including containment measures, decontamination procedures, and notification processes to mitigate risks and minimize the impact on public health and safety.

10.8 Conduct a thorough stakeholder analysis

Mali should conduct a thorough stakeholder analysis to identify and engage a diverse range of stakeholders involved in the management of dangerous pathogens, including those beyond the public health sector. This analysis should consider the roles, interests, and expertise of each stakeholder group to ensure comprehensive representation in the improvement of the National Inventory of Dangerous Pathogens.

10.9 Develop targeted awareness campaigns

Mali should develop targeted awareness campaigns to educate key stakeholders about the risks associated with dangerous pathogens and the importance of collaborative action in addressing them. These campaigns should aim to raise awareness among policymakers, healthcare professionals, researchers, and the general public about the potential threats posed by dangerous pathogens and the need for proactive measures to prevent and control their spread. By fostering greater awareness and understanding, Mali can build support for efforts to improve the National Inventory of Dangerous Pathogens.

10.10 Train Laboratory Technicians after every six months

Regular training of laboratory technicians on the tools for collecting information on dangerous pathogens and toxins, and the factors influencing disease risk classification is essential for maintaining public health and biosafety standards. By equipping technicians with the necessary knowledge and skills, this training program aims to enhance their capacity to contribute effectively to identification of dangerous pathogens and toxins, disease surveillance, risk assessment, and mitigation efforts. Through continuous learning and skill development, they can strengthen their preparedness and response to emerging diseases threats.

10.11 Maintain the update of WAMPServer and Windows 11

To ensure the security and robustness of NIAPD, it's essential for the IT Manager, Data Manager, and Biosafety and Biosecurity Officer to collaborate closely in maintaining the update of critical software like WAMPServer and the operating system Windows 11. This

involves establishing a regular update schedule, implementing a patch management system for timely deployment, conducting risk assessments to prioritize updates, adhering to change management processes, maintaining backups for recovery, monitoring update status. By following these steps, INSP can mitigate vulnerabilities, enhance NIAPD security, and optimize performance, ultimately safeguarding against potential threats and disruptions.

10.12 ISNP should engage in collaborations with pre-veterinary laboratories to address the issue of Antimicrobial Resistance (AMR)

Collaborating with pre-veterinary laboratories offers the ISNP a valuable opportunity to tackle Antimicrobial Resistance (AMR) comprehensively. Through resource sharing and expertise exchange, ISNP can analyze samples collected by pre-veterinary labs. This collaboration facilitates joint research projects, education initiatives, and advocacy efforts aimed at combating AMR effectively. By leveraging their respective strengths, ISNP and pre-veterinary laboratories can contribute significantly to the global effort to address dangerous pathogens (AMR resistance microorganisms).

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