Assessment of the Biorisk Status of Veterinary Laboratories in Southwest Nigeria: Application of the Food and Agriculture Organization Laboratory Mapping Tool-Safety Module

Oluwawemimo Adebowale[1,*], Adebankemo Oduguwa[1], Saheed Dipeolu[1], Michael Agbaje[2], Olubumni Fasanmi[3], and Folorunso Oludayo Fasina[4,5]

[1]Department of Veterinary Public Health and Reproduction, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

[2]Department of Microbiology and Parasitology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

[3]Federal College of Animal Health and Production Technology, Ibadan, Nigeria

[4]Emergency Center for Transboundary Animal Diseases, Food and Agriculture Organization of the United Nations, Dar es Salaam, Tanzania

[5]Department of Veterinary Tropical Diseases, University of Pretoria, South Africa

*Corresponding Author:
Adebowale Oluwawemimo, Department of Veterinary Public Health and Reproduction, Federal University of Agriculture Abeokuta, Ogun State, Nigeria.
Email: oluwawemimo1@yahoo.com

Abstract

Introduction: Because of the nature of work conducted in veterinary laboratories and potential exposures to pathogenic microorganisms, good laboratory practices, risk assessments, biosafety, and biosecurity capacity is becoming vital. In this study, the Food and Agriculture Organization Laboratory Mapping Tool-Safety Module was applied to demonstrate its practical implementation in the assessment of biosafety and biosecurity statuses of veterinary laboratories in Nigeria.

Methods: The Laboratory Mapping Tool-Safety Module, a standardized questionnaire, systematically and semiquantitatively gathered data on 98 subcategories covering 4 areas of biosafety and biosecurity capabilities: administrative, operational, engineering, and personal protective equipment.

Results: Overall, the various areas and categories covered by the Laboratory Mapping Tool-Safety Module were weak across the board, with a mean performance of 19.5% (95% confidence interval, 14.0%-25.1%; range, 0.8%-29.6%). The weakest functionality was in emergency preparedness (0.8%; ie, emergency responses and exercises such as fire drills, spill cleanup, and biological spill kit availability). Also, many laboratories were deficient in metrology procedures, biosafety cabinets, chemical hazard containment, regular maintenance and external calibration procedures for laboratory equipment, and personnel health and safety. However, a few functionalities within individual laboratories scored above average (50%), for example, a university microbiology laboratory animal facility (100%).

Interlaboratory comparison indicated that biosafety and biosecurity performance was similar across laboratories ($P = .07$) and did not vary by location ($P = .37$).

Conclusions: Significant biosafety and biosecurity improvements are needed to guarantee the health and safety of workers and the global community, efficient responses to infectious disease containment, and compliance with the Global Health Security Agenda.

Keywords: veterinary laboratory, biosafety and biosecurity, FAO LMT-S, global health, Nigeria

Laboratory biosafety is considered to be "the containment principles, technologies, and practices that are implemented to prevent intentional exposure to pathogens and toxins or their accidental release."[1] Likewise, biosecurity describes "the protection, control, and accountability for valuable biological materials within laboratories, to prevent their unauthorized access, loss, theft, misuse, diversion or intentional release."[1] These concepts are consistent across the World Health Organization's International Health Regulations (2005) Joint External Evaluation indicators P.6.1 and P.6.2 (biosafety and biosecurity), the Global Health Security Agenda's Action Package Prevent-3 (biosafety and biosecurity), and other global health security platforms supported by the World Organisation for Animal Health, the Food and Agriculture Organization (FAO) of the United Nations, and other such bodies.[2] These all contribute to relevant guidance and regulations for safeguarding public and animal health. The terms "biosafety" and "biosecurity" are used interchangeably, but the differences between the 2 concepts have been specified academically. In practice, when one is working hands-on in a laboratory, it is more difficult to draw such distinctions.[2]

Veterinary laboratories (VLs) are an essential component of global public health, through their involvement in disease diagnosis, surveillance, and control.[3] VLs play vital roles in the detection of zoonotic and animal-specific diseases, in food safety, and in the production and development of vaccines and therapeutic strategies for both humans and animals.[3] Given the nature of the work conducted in VLs and potential exposures to pathogenic microorganisms, protection of personnel and community and environmental health are vital and require good laboratory practices, risk assessments, and biosafety and biosecurity measures. Biological agents pose a severe threat to human health, economic development, social stability, and even national security.[4] Therefore, critical elements in laboratory biosafety and security must include control of potential hazards to biological, physical, chemical, and radiologic materials. These critical components could be achieved through the use of personal protective equipment (PPE), engineering controls for equipment and facilities, decontamination and waste control management, administrative controls (eg, hazard communication and signage), guidelines and regulatory compliance, safety program management, occupational health, medical surveillance, risk management, and emergency preparedness and response, which includes emergencies and incident response, exposure prevention and hazard mitigation, and emergency response (eg, exercises and drills).[5] These requirements must be fulfilled to run a VL safely and adequately to deliver reliable and reasonable analytic results that can be trusted and used by authorities and other stakeholders.[5]

Recently, emerging and reemerging infectious and zoonotic diseases are increasing threats, particularly in Africa, including those with bioterrorism potential.[6,7] Concerns surrounding the deliberate or accidental release of potentially pathogenic microorganisms have driven the

debate regarding the restriction of access to high-consequence pathogens and improving biosecurity measures, especially for those pathogens that have the potential to spread rapidly in the community.[8] As emerging and recurring global health threats expand their frontiers, in the short and longer terms, sustainable strategic approaches are needed to mitigate their impacts. Adequate biosafety and biosecurity systems, including infrastructure, stringent regulatory practices, and enforcement of regulations, must exist to militate against the spread and global impact of (re)emerging infectious diseases. Unfortunately, such systems are not in existence or are not as robust as in high-income communities,[8] and it may become challenging for African countries to comply with and work toward promoting the GHSA. The lags and inconsistencies in laboratory biosafety and biosecurity systems can be attributed to differences in national and local infrastructures, availability of funds, differing priorities and regulatory frameworks, and accessibility to expertise, training, and equipment.[9]

In compliance with the GHSA, capacity building toward reliable and adequate veterinary care, disease diagnosis, and disease control and prevention is the primary focus of the FAO. To support these goals, the FAO developed and released a veterinary biosafety assessments tool, the Laboratory Mapping Tool-Safety Module (LMT-S), in 2015. The LMT-S together with the LMT-Core is an appropriate tool in the provision of evidence and in understanding where biosafety and biosecurity strengths and gaps exist in diagnostic laboratories. Through this identification, strategic plans that will match individual, national, and regional laboratory needs can be developed and typified.[5]

In Africa, detailed studies of laboratory biosafety and biosecurity are uncommon.[10,11] For instance, in Nigeria, only 1 study assessed the level of knowledge of laboratory biosafety at veterinary research facilities.[6] Elsewhere, several studies have focused on laboratory biosafety and biosecurity as they relate to laboratory scientists,[12,13] clinical microbiology laboratories,[14,15] medical diagnostic laboratories,[10,16] and pharmaceutical and biotechnology laboratories[10] that work with human pathogens, but little on animal biosafety. To the best of our knowledge, this is the first study in Nigeria to apply the FAO's LMT-S for preliminary VL assessments to determine current biosafety and biosecurity status. Such measurements and the resulting progress and impact can be assessed and compared in the future with the baseline data generated in this study.

Methods

Study Locations

This study was conducted in 2 southwestern states (Oyo and Ogun) in Nigeria. The estimated population of Ogun state was 5,217,716 in 2013, according to the National Population Commission and the National Bureau of Statistics. Of Nigeria's 36, Ogun is ranked 24th in land area, at 16,980.55 km^2.[17] It is bordered to the south by Lagos, to the north by Oyo and Osun, to the east by Ondo, and to the west by the Republic of Benin.

Oyo is an inland state in southwestern Nigeria; its capital is Ibadan. Oyo is ranked 14th in land area, at 24,454 km^2. It is bounded to the north by Kwara, to the east by Osun, to the south by Ogun, and to the west partly by Ogun and partly by the Republic of Benin. As of 2006, Oyo had a total population of 5,580,894.[17]

Study Design

Selection of Veterinary Diagnostic Laboratories

Eleven laboratories were conveniently but purposively selected for this study, including (1) 7 VLs that were based at academic institutions (3 microbiology, 2 parasitology, and 2 pathology laboratories), (2) 2 government veterinary clinic and laboratories in each state, (3) 1 private VL, and (4) 1 national VL based in southwestern Nigeria. All laboratories were coded appropriately to exclude individual identification, and states were coded as regions A and B. The inclusion criteria for laboratories were performance of veterinary diagnostics, location within the study area, and establishment of minimum standards against which assessment might be carried out. Before the commencement of the study, official letters from the University of Agriculture in Abeokuta, Nigeria, that briefly described the scope of the study and requested for consent were provided to respective heads of laboratories. Positive responses of participants commenced the questionnaire process. Participating laboratories were made aware of their right not to complete the questionnaire or some questions within the questionnaire or to disengage from the study at any period during the questionnaire process without providing any reason. The field study was carried out between May 30 and September 30, 2018.

Table 1. Areas and Categories Covered by the Safety and Biosecurity Module of the Food and Agriculture Organization Laboratory Management Tool, 2018.

Area	Category	Number of Associated Subcategories (Total 98)
Administration	General	5
	Personnel health and safety	4
	Training and competency	4
	Biosafety manual/standard operating procedures	2
Operations	Good laboratory practices	7
	Containment	6
	Containment BSL-3	8
	Waste disposal	5
	Shipping of infectious substances	5
Engineering	Animal facilities	7
	Premises	7
	Chemical hazard containment	6
	Chemical security	4
	Emergencies	4
	Fire hazard	4
	Electrical	4
	Biosafety cabinet	3
PPE	Chemical hazard containment	6
	General situation	4
	Use of PPE	4
	PPE disposal	5

Abbreviations: BSL, biosafety level; PPE, personal protective equipment.

LMT-S and Data Collection

The FAO developed and released the LMT-S in 2015. The LMT-S is modeled after the LMT-Core, which is a standardized questionnaire that gathers data and evaluates laboratory functionalities, including aspects of biosafety and biosecurity, in a systematic and semiquantitative manner. A copy of the questionnaire is provided in the supplementary material. The LMT-S questionnaire is formatted into 4 safety and biosecurity areas: (1) administration, (2) operational, (3) engineering, and (4) PPE. The 4 areas were further divided into 20 categories and 98 subcategories. Table 1 provides details of areas, categories, and the subcategories covered by the LMT-S.

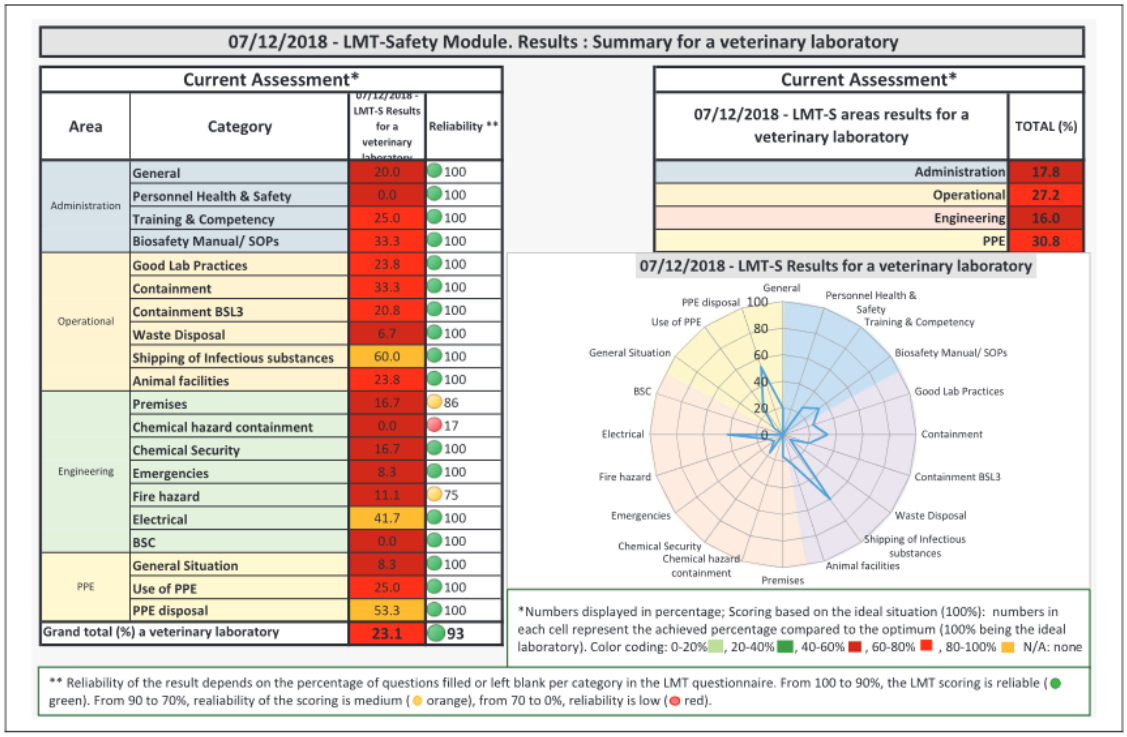

Figure 1. A summary assessment and reliability report of the Laboratory Mapping Tool-Safety Module for one of the veterinary laboratories.

The laboratories were scored on the basis of observations and interviews with the heads of respective units of laboratories. The supplementary material provides details of the LMT-S questionnaire, guidelines for its use, and scoring options. For each of 98 questions, 1 of 4 options per row that best described the situation on the basis of the evaluator's assessment and evaluation was recorded. Column C, current assessment, was used to record scores. "N/A" (column J) was checked whenever information was not applicable. If N/A was checked, this subcategory was not taken into consideration in the summary score. Whenever 2 scores could apply to a given situation, 1 score was selected, and the reason for hesitation was provided in the column for assessor's comments (column K). Column K offers a space for assessors to narrate further and document their assessment observations. Additional information for assessors was specified in column L. The scoring within the LMT-S module is based on a maximum percentage of 100%, expected in an ideal situation (ie, when a laboratory scores 4 in all subcategories). A reliability score was additionally calculated and reported as a component of the summary reports (Figure 1). Completion of 0% to 69% of the

questionnaire provides low reliability, 70% to 89% a medium confidence score, and 90% to 100% of the questionnaire is ranked as reliable.[3]

Statistical Analysis

The complete LMT-S questionnaire sheet was imported into the LMT automated analytic tool. Once the LMT questionnaire sheet was filled, the "summary" sheet with visualization of scores as subvalues and graphs for the 4 areas and 20 different LMT categories was presented. Also, graphical depictions of laboratory functionalities with respect to strengths and weaknesses were generated. Scores as percentages were compared with the optimal ideal laboratory (100%). Laboratory biosafety and biosecurity capacities were generally categorized as deficient (0%-39%), moderate (40%-69%), or strong (>70%). Interlaboratory comparison in terms of functionality performance was also conducted using (1) mean scores estimated with Microsoft Excel (Microsoft, Redmond, WA) and Stata (StataCorp, College Station, TX) and (2) ordinary 1-way analysis of variance and Tukey's multiple-comparisons test.

Results

The LMT-Core tool achieved a medium degree of confidence (mean reliability score, 78.2%) for this assessment. The current assessment findings showed that among the 11 laboratories that participated in the study, 6 (54.5%) were located in region B and 5 (45.5%) in region A. Pathogen types handled by laboratories included bacteria at 8 (72.7%), viruses at 4 (36.3%), fungi or *Mucor* at 3 (27.2%), and parasites at 6 (54.5%). Across all the categories assessed, a mean performance score of 20.6 ± 8.8% (range, 8.1%-33.8%) was recorded for laboratories based in region B, while those in region A score 18.3 ± 8.3% (range, 9.4%-29.8%). The performance of laboratories in the different areas of biosafety and biosecurity is described in Figure 2.

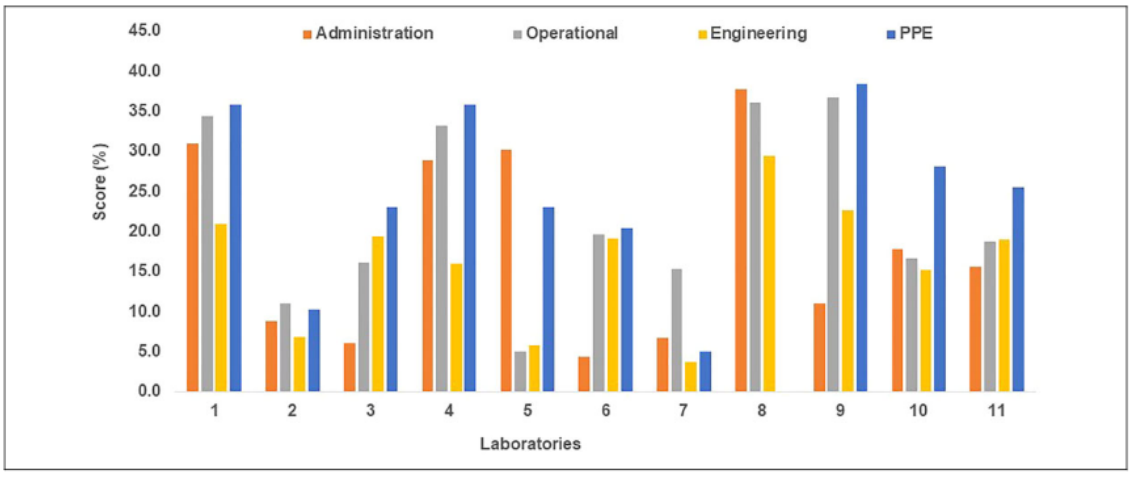

Figure 2. Summary outcome of the Laboratory Mapping Tool-Safety Module areas assessed for veterinary laboratories in this study. Categories of laboratories and facilities (see Table 2 for definitions of abbreviations): 1 = PC, 2 = Uni-Para; 3 = Uni-Path; 4 = Uni-Mic; 5 = Pub Vet C&L; 6 = Inst Mic; 7 = Pub 2 Vet C&L; 8 = Inst L&V; 9 = Uni 2-Mic; 10 = Uni 2-Para; and 11 = Uni 2-Path.

Overall, biosafety and biosecurity were reported generally as inadequate, with mean performance of 19.5% (95% confidence interval, 14.0%-25.1%; range, 8.1%-33.8%) (Table

Table 2. Categories of Laboratory Functionalities and Facilities Assessed Using the Laboratory Mapping Tool-Safety Module in Southwestern Nigeria, 2018.[a]

	Facility	G	PHS	TC	BMS	GLP	C	CBLS3	WD	SIS	AF	P	CHC	CS	E	FH	E+	BSC	GS	UPPE	PPED	Grand Total
Region A	PC	46.7	8.3	41.7	0.0	23.8	33.3	N/A	33.3	53.3	33.3	28.6	33.3	0.0	0.0	33.3	50.0	0.0	33.3	41.7	33.3	29.8
	Uni-Para	13.3	0.0	8.3	16.7	4.8	5.6	11.1	6.7	26.7	14.3	0.0	0.0	0.0	0.0	33.3	16.7	0.0	8.3	0.0	20.0	9.4
	Uni-Path	13.3	0.0	0.0	0.0	28.6	0.0	0.0	26.7	6.7	33.3	23.8	0.0	25.0	0.0	0.0	50.0	N/A	33.3	8.3	26.7	16.9
	Uni-Mic	20.0	0.0	25.0	33.3	23.8	33.3	20.8	6.7	60.0	23.8	16.7	0.0	16.7	8.3	11.1	41.7	0.0	8.3	25.0	53.3	23.1
	Pub Vet C&L	40.0	11.1	50.0	0.0	8.3	0.0	0.0	0.0	20.0	0.0	16.7	0.0	0.0	0.0	8.3	0.0	N/A	33.3	16.7	20.0	12.3
	Inst-Mic	6.7	0.0	8.3	0.0	28.6	27.8	N/A	13.3	0.0	N/A	33.3	66.7	16.7	0.0	16.7	25.0	0.0	0.0	16.7	40.0	16.7
	Pub 2 Vet C&L	6.7	0.0	8.3	16.7	14.3	5.6	N/A	0.0	46.7	0.0	14.3	0.0	0.0	0.0	0.0	0.0	N/A	0.0	0.0	13.3	8.1
	Inst L&V	40.0	41.7	41.7	16.7	42.9	38.9	N/A	33.3	33.3	0.0	52.4	33.3	8.3	0.0	8.3	58.3	33.3	N/A	N/A	N/A	33.8
Region B	Uni 2-Mic	26.7	0.0	8.3	0.0	42.9	27.8	N/A	0.0	0.0	100.0	33.3	0.0	25.0	0.0	8.3	41.7	33.3	41.7	41.7	33.3	26.9
	Uni 2-Para	40.0	8.3	8.3	0.0	44.4	5.6	N/A	0.0	0.0	0.0	33.3	0.0	16.7	0.0	8.3	16.7	N/A	16.7	33.3	33.3	18.6
	Uni 2-Path	26.7	16.7	8.3	0.0	33.3	6.7	0.0	0.0	0.0	40.0	38.1	0.0	0.0	0.0	16.7	25.0	N/A	25.0	33.3	20.0	19.4
	Mean value	25.5	7.8	18.9	7.6	26.9	16.8	6.4	10.9	22.4	24.5	26.4	12.1	9.9	0.8	13.1	29.6	11.1	20.0	21.7	29.3	19.5
	Median																					
	SEM	4.4	3.8	5.3	3.5	4.1	4.6	4.2	4.1	7.0	9.8	4.3	6.8	3.1	0.8	3.4	6.1	7.0	4.8	5.0	3.7	2.5
	95%CI	15.7–35.2	-0.7–16.3	7.1–30.7	-0.1–15.3	17.7–36.1	6.6–27.0	-5.3–18.0	1.6–20.1	6.9–38.0	2.4–46.6	16.9–35.9	-3.0–27.2	2.8–16.9	-0.9–2.4	5.5–20.7	16.0–43.1	-6.9–29.1	9.0–30.9	10.4–33.0	20.9–37.8	14.0–25.1

[a] All values are expressed as percentages.

Abbreviations: Functionality categories assessed: AF, animal facilities; BMS, biosafety manual/standard operating procedures; BSC, biosafety cabinet; C, containment; CBLS3, containment biosafety level 3; CHC, chemical hazard containment; CS, chemical security; E, emergencies; E+, electrical; FH, fire hazard; G, general; GLP, good laboratory practices; GS, general situation; P, premises; PHS, personnel health and safety; PPED, personal protective equipment disposal; SIS, shipping of infectious substances; TC, training and competency; UPPE, use of personal protective equipment; WD, waste disposal. Categories of laboratories and facilities: Inst L&V, institution with laboratory and vaccine supply chain; Inst-Mic, training institution microbiology; PC, private clinic; Pub 2 Vet C&L, second state veterinary clinic and laboratory; Pub Vet C&L, state veterinary clinic and laboratory; Uni 2-Para, second university parasitology; Uni 2-Mic, second university microbiology; Uni 2-Path, second university pathology; Uni-Mic, university microbiology; Uni-Para, university parasitology; Uni-Path, university pathology. Other: CI = confidence interval; N/A = not available; SEM = standard error of the mean.

2). Interlaboratory performance comparison showed that biosafety and biosecurity capacities or measures were similar across the board ($P = .07$). The weakest score observed was in the category of emergency preparedness (0.8%; ie, emergency responses or exercises such as fire drills, spill cleanup, biological spill kit availability, and other emergency procedures). Among the 20 biosafety and biosecurity functionalities investigated, 11 (55.5%) were below the overall mean performance (19.5%), including personnel health and safety (7.8%); formal training and competence of staff members in biosafety and biosecurity (18.9%); biosafety manuals and technical standard operating procedures for specific operations and procedures (7.6%); containment, especially risk assessment, access security measures, biohazard signage, and handling of pathogenic infectious organisms (16.8%); waste disposal of sharps and infectious pathogens (10.9%); chemical hazard containment (12.1%); containment biosafety level (BSL) 3 (6.4%); chemical security practices (eg, presence of a chemical safety officer, chemical spill kits, and chemical storage) (9.9%); fire hazard control (13.1%); and use and conformity of biosafety cabinets (BSCs) (11.1%) (Table 2). The biosafety and biosecurity scores were compared and were similar ($P = .37$) in both states.

For individual laboratories, only a few functionalities within each facility performed well (ie, above average). For instance, 1 of the university microbiology facilities provided the highest strength among animal facilities (100%), while moderate scores were reported for staff training and competence in biosafety procedures (50%) in a laboratory associated with the public veterinary clinics and electrical installation standards in a private and university pathology laboratory (50%), shipment of infectious substances procedures (60.0%), and PPE disposal (53.3%) in 1 of the university microbiology laboratories.

Discussion

The LMT-S was designed specifically to target all aspects of biosafety and biosecurity as critical components of building efficient veterinary public health infrastructure nationally, regionally, and globally.[3] The tool can be used by laboratories to establish a baseline status before an intervention and to measure progress made through interventions against this baseline.[18] The degree of reliability of the tool depends on the accuracy of input obtained from respondents and the quality of the test instrument. In this case, quality, unbiased data were obtained from laboratory managers, and on-site data verification was conducted at each facility. The tool has been used in at least 14 African countries, and the outputs and recommendations have been used for the improvement of laboratories in these countries with a significant degree of successes. Much more important, LMT-S output is consistent with the Joint External Evaluation protocol of the World Health Organization's International Health Regulations.[19] The tool provides standardized data necessary for updating the GHSA Joint External Evaluation to identify strengths and weaknesses within health systems in order to prioritize the health systems (ie, veterinary, public, environmental) and access opportunities such as funding for capacity building.[3] Finally, the LMT is consistent with the objectives of the GHSA, perhaps the most important and widely accepted health agenda.

This pilot assessment of VLs in southwestern Nigeria confirmed that laboratories' biosafety and biosecurity are poorly implemented, and performance levels were below those recommended in internationally recognized biosafety and biosecurity guidance documents.[3] An earlier study conducted in Nigeria raised concern about the levels of negligence in laboratory biosafety and biosecurity at VL facilities in the country.[6] Laboratories visited in this study lack BSL facilities and functional BSCs. The majority of the laboratories provide teaching, research, diagnostic, and healthcare services (public health, clinical, or hospital

based) and supposedly should be designed as BSL-2 or above. Despite these inadequacies, researchers still work with highly pathogenic microorganisms such as *Mycobacterium* spp, *Brucella* spp, and rabies and highly pathogenic avian influenza viruses, which should be handled at BSL-3 facilities, increasing exposure to laboratory-acquired infections and undermining public safety. This corroborates reports from a past study.[6]

Waste handling, isolation, storage, and disposal of infectious materials and samples and infectious pathogens was inappropriate across all laboratories visited. Poor disposal of infectious materials could pose inherent safety and security risks to public and environmental health. Laboratory biosafety and biosecurity systems must be a built-in part of any laboratory working with and handling dangerous microorganisms to prevent accidental and intentional release.[20] For instance, the laboratories visited had no functional incinerators, and most waste materials were disposed of by burial without prior decontamination. In an ideal setting, infectious waste would be disposed of in labeled biohazard plastic bags, with decontamination by autoclaving or chemical treatment before incineration. Indeed, there is need for the staff of VLs in the country to undergo updated training and consciously plan out statutory rules and regulations to improve and maintain standards in the prevention of the unintentional release of or accidental exposure to biological agents and toxins and to physically control biological agents via proper waste management strategies.[21]

Shipping of infectious substances was observed to be quite inadequate except at 2 laboratories, which on average met the international standards. Because of the risks infectious materials pose to health and safety, their handling and transportation must be strictly regulated nationally and internationally. Within the country, there are no strict national criteria or standards for the shipment of infectious materials, whereas international regulations are strictly adhered to, especially when materials are to be transported outside the country. Staff training on classification, documentation, labeling and packaging, and transportation to reduce damage and leaks and possible exposures to infection or disease is crucial.[19] This work shows that proactive development and stringent implementation of national guidelines and standards for safe transportation, by air, road, or rail within the country, is mandatory.

Laboratory management in biohazard containment such as access security measures and restrictions, training and competency, risk assessment for biocontainment of hazardous pathogens, biohazard signage, emergency response plans, the presence of updated standard operating procedures, the availability and use of BSCs, and PPE were areas of weakness reported across the laboratories investigated. A past study documented the poor level of knowledge of laboratory biosafety management, which further suggested an inadequate level of understanding of biosafety and biosecurity at VLs in Nigeria.[6] The lack of biosafety risk assessment observed implies that laboratories have not analytically characterized the level of safety risks associated with infectious pathogens handled and other different procedures in the laboratory. Furthermore, laboratories cannot predict or provide proactive action plans to mitigate biohazards, and in the event of biosafety and biosecurity breakdowns, possible exposure of personnel, the public, and the environment to infectious pathogens increases.[6] General requirements for laboratory biosafety according to GB 19489-2008 state that "when laboratory activities involve infectious or potentially infectious biological factors, the risk assessment of the extent of the hazards must be carried out."[22] Thorough risk assessments improve the BSLs of laboratories in terms of housing target biological factors, the formulation of corresponding standard operating procedures, laboratory management systems, and emergency treatment methods to avoid imminent risks.[22]

Moreover, the low performance in PPE use and disposal practices, as well as the use of BSCs, generates concerns especially with respect to laboratory personnel safety from biohazardous materials. The exposure risks to laboratory infections through skin contamination and inhalation are possibly heightened by the lack of PPE and appropriate BSCs. When used correctly, PPE is the last line of defense that protects individual workers from the most hazardous pathogens and chemicals. PPE selection is routinely based on a risk assessment of the work conducted and the pathogens handled by a laboratory. A variety of PPE is commercially available to prevent serious safety injuries, including laboratory coats, closed-toed shoes, safety glasses, eye and face shields, respirators, and gloves. The effectiveness of PPE to reduce risk also relies on administrative and especially staff training on use: donning and doffing and waste disposal practices and operational controls regarding its purchase and storage.[6] PPE use and disposal procedures must also be monitored to ensure effective risk management.[20]

Conclusions

Global concerns over emerging and reemerging infectious diseases have had a huge impact in veterinary sectors, with additional concerns over the biosafety and biosecurity capacities of VLs, especially those in developing countries where resources are commonly limited. The LMT-S provided a standardized and independent assessment of strengths and gaps in the biosafety and biosecurity of VLs in southwestern Nigeria. The present assessment showed that biosafety and biosecurity capacities are inadequate in all the VLs investigated. There is a need to raise awareness and to improve information and communication through focused training on laboratory management, risk assessments, biosafety and biosecurity procedures and facilities, and other essential competencies required by laboratories to ensure animal disease containment and workplace and environmental safety. Conscious effort and commitment of public health stakeholders at national and local levels to improving biosafety amenities and practices, knowledge acquisition and sharing through improved regional and international networks, and partnerships and collaborations are critical for scaling up laboratory capacities and biosafety in the country.

Acknowledgments

This study was made possible by the cooperation of all the laboratory heads and staff members who participated.

Data Availability

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available, because they contain information that could compromise the privacy of participating laboratories.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval Statement

Not applicable to this study.

Statement of Informed Consent

Informed consent was sought from and provided by the respective heads of laboratories. Positive responses to participate in the study commenced the questionnaire filling process. Participating laboratories were made aware of their right not to fill in the questionnaire or some questions within the questionnaire or disengage from the study at any period during the questionnaire process without providing any reason.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD: Oluwawemimo Adebowale https://orcid.org/0000-0002-4207-7423

References

1. World Health Organization. *Biorisk Management: Laboratory Bio-security Guidance*. World Health Organization Epidemic and Pandemic Alert and Response (WHO/CDS/EPR/2006.6). Published 2006. Available at: http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_EPR_2006_6.pdf. Accessed May 6, 2018.
2. Coelho AC, D´ıez JG. Biological risks and laboratory-acquired infections: a reality that cannot be ignored in health biotechnology. *Front Bioeng Biotechnol*. 2015;3: 56.
3. Mouill´e B, Dauphin G, Wiersma L, et al. A tool for assessment of animal health laboratory safety and biosecurity: the safety module of the Food and Agriculture Organization's Laboratory Mapping Tool. *Trop Med Infect Dis*. 2018;3(1):33-43.
4. Tian D, Zheng T. Comparison and analysis of biological agent category lists based on biosafety and biodefense. *PLoS ONE*. 2014;9(6): e101163.
5. Food and Agriculture Organization of the United Nations. Strengthening Veterinary Diagnostic Capacities: the FAO Laboratory Mapping Tool. http://www.fao.org/3/a-i5439e.pdf. Accessed May 6, 2018.
6. Odetokun IA, Jagun-Jubril AT, Onoja BA, et al. Status of laboratory biosafety and biosecurity in veterinary research facilities in Nigeria. *Saf Healtht Work*. 2017;8(1):49-58.
7. Muzemil A, Fasanmi OG, Fasina FO. African perspectives: modern complexities of emerging, re-emerging, and endemic zoonoses. *J Glob Health*. 2018;8(2):1-6.
8. Siengsanan-Lamont J, Blacksell S. A review of laboratory-acquired infections in the Asia-Pacific: understanding risk and the need for improved biosafety for veterinary and zoonotic diseases. *Trop Med Infect Dis*. 2018:3(2):36-46.
9. Dickmann P, Sheeley H, Lightfoot N. Biosafety and biosecurity: a relative risk-based framework for safer, more secure, and sustainable laboratory capacity building. F*ront Public Health*. 2015;3: 241-247.

10. Astuto-Gribble LM, Gaudioso JM, Caskey SA, et al. A survey of bioscience research and biosafety and biosecurity practices in Asia, Eastern Europe, Latin America, and the Middle

East. *Appl Biosaf*. 2009;14(4):181-196.
11. Kirunda H, Otimonapa M. Low level of awareness in biosafety and biosecurity among professionals in Uganda: a potential risk in the dual-use dilemma. *J Bioterror Biodef*. 2014;5: 1-10.
12. Zavery J. Knowledge attitudes and practice of laboratory technicians. *Nat J Med Res*. 2012;2(1): 113-115.
13. Deveci O, Tekin R, Aslan E, et al. Assessment of the laboratory transmission of brucellosis in an endemic region. *Acta Med Mediterranea*. 2014;30: 205-208.
14. Ergönül O, Çelikbas A, Tezeren D, et al. Analysis of risk factors for laboratory-acquired brucella infections. *J Hosp Infect*. 2014; 56(3):223-227.
15. Bouza E, Sánchez-Carrillo C, Hernangómez S, et al. Laboratory acquired brucellosis: a Spanish national survey. *J Hosp Infect*. 2005;61(1):80-83.
16. Oladeinde B, Omoregie R, Odia I, et al. Bio-risk assessment of medical diagnostic laboratories in Nigeria. *Saf Health Work*. 2013;4(2):100-104.
17. National population commission and National Bureau of Statistics. 2013. Available at: https://en.wikipedia.org/wiki/Ogun_State. Accessed February 13, 2019.
18. Blacksell SD. Supporting implementation of the OIE biorisk standard: new Laboratory Mapping Tool [abstract]. Presented at: World Association of Veterinary Laboratory Diagnosticians 18th International Symposium; Sorrento, Italy; June 7-10, 2017.
19. World Health Organization. Joint External Evaluation Tool. 2nd ed. Technical framework in support to international health regulations monitoring and evaluation Published. 2005. Available at: https://extranet.who.int/sph/joint-external-evaluation-tool-2nd-edition. Accessed October 19, 2019.
20. Brass VH, Astuto-Gribble L, Finley MR. Biosafety and biosecurity in veterinary Laboratories. *Rev Sci Tech*. 2017;36(2):701-709.
21. World Organisation for Animal Health. Biosafety and biosecurity: standard for managing biological risk in the veterinary laboratory and animal facilities. In *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals*. Published 2015. Available at: http://www.oie.int/international-standardsetting/terrestrial-manual/access-online. Accessed January 21, 2019.
22. Li N, Hu L, Jin A, et al. Biosafety laboratory risk assessment. *J Biosaf Biosec*. 2019;1(2):11-13.