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Low Level of Awareness in Biosafety and Biosecurity among Professionals in Uganda: A Potential Risk in the Dual-Use Dilemma

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Abstract

Disease diagnosis, and analysis or manipulation of both human and animal samples, expose scientists and practitioners to disease causing agents and toxins. In situations of poor awareness of biosecurity, the same samples can easily be accessed by persons with wrong intentions or misused by the same scientists or practitioners (dual-use). In Uganda information required to minimize the global challenges of biosafety and biosecurity has been largely lacking. The current study assessed the level of awareness and existence of procedures, regulations, laws and policies on biosafety and biosecurity among institutions in the different sectors, professions and regions across the country. Results showed that sector, profession and region were each a predictor for nine of the assessed variables. Among the most striking was that profession significantly influenced (χ^2=49.0) the opinion that institutional measures to prevent or prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins existed. Professionals (veterinary scientists and laboratory technologists) in animal health research had reduced odds of holding this opinion (OR=0.2, 95% CI: 0.05-0.87) compared to their counterparts in public hygiene. Scientific establishments in eastern (OR=0.3, 95% CI: 0.17-0.7, p<0.01), northern (OR=0.4, 95% CI: 0.17-0.71, p<0.01) and western (OR=0.3, 95% CI: 0.16-0.51, p<0.01) regions were less associated with professionals trained in biosafety and biosecurity compared to central Uganda. Professionals in wildlife conservation, medical, human health research, public hygiene and crop extension services were 9.5, 7.0, 5.7, 5.4 and 4.0 times, respectively, more likely to consider Uganda's disease monitoring system as adequate compared to those in veterinary services sector. We conclude that there is inadequate level of awareness on laboratory biosafety and biosecurity among professionals in the country. There is need for raising awareness and training of relevant professionals and formulation of measures, policies, regulations and laws to help prevent exposure to and misuse of dangerous biological agents and toxins in Uganda.

Keywords: Biosafety; Biosecurity; Dual-use, Measures; Laws; Policies; Procedures

Introduction

Biological materials are handled worldwide in laboratories for numerous genuine, justifiable and legitimate purposes. In these laboratories small and large volumes of live microorganisms are replicated, cellular components are extracted and many other manipulations undertaken for purposes ranging from educational, scientific, medicinal and health-related to mass commercial and/or industrial production [1]. During handling of these materials, it is expected that personnel follow safe working practices (biosafety) and apply measures that help keep their work and materials safe and secure (biosecurity). They are also expected to follow an ethical code of conduct (bioethics) [2]. Acceptable work practices, procedures and facilities have been extensively described [3]. A comprehensive biosafety culture is known to translate into the understanding and routine application of a set of safe practices, procedures, actions and habits that protect the people working with biological materials [1]. Whereas biomedical advances and the globalization of scientific and technical expertise have made it possible to greatly improve public health, a global increase in exposure, availability and accessibility to potentially harmful technology has remained one of the major challenges in biosecurity and biosafety [4]. Negotiating global standards that restrict access to dangerous pathogens is hoped to reduce the threat of bioterrorism, as reinforcing the legal prohibitions on the development, production, and stockpiling of biological and toxin weapons contained in the 1972 Biological Weapons Convention (BWC) is being undertaken (http://www.armscontrol.org/print/1314). In Uganda, over five hundred laboratories comprising government, non-governmental organizations and private establishments handle materials ranging from non-pathogenic to those that were highly infectious [5]. The nature and volume of material handled as well as the level of training of staff in these establishments is not clearly documented [6]. The country neither has an accurate record of laboratories nor the organisms scientists are working with, and the levels of biosafety and biosecurity of the particular laboratories [7]. The national biotechnology and biosafety Act enacted in Uganda in 2010 only considered the Cartagena Protocol on biosafety and did not adequately address biosafety in the broader context beyond genetically modified crops [8]. A study by the Food and Agriculture Organization of the United Nations (FAO) [9] reported that biosecurity as a concept has not been specifically addressed by policy or law in Uganda. Biosecurity agenda in Uganda has been largely managed based on guidelines of international frameworks such as the biological and toxin weapons convention of 1972, the International Health Regulations of 2005, and International Office of Epizootics (OIE) guidelines, among

others. The FAO study also recommended that, although Uganda National Council for Science and Technology (UNCST) was leaning towards biotechnology and biosafety, it should embrace biosecurity as a whole.

There is a global increase in challenges of biosecurity including the increase in availability of invasive alien species, globalization, emerging infectious diseases, global change and accessibility of potentially harmful technology such as those used in genetic modification [10]. There is also the risk that advances can lead to making of biological weapons [11]. Uganda is located in the great lakes region, a place occasionally regarded as a hub of diseases. In the recent past, the country has had increased frequency of emerging infectious disease pathogens such as Hemorrhagic Fever viruses (Ebola and Marburg) virus, Hepatitis B and E viruses, Foot-and-mouth disease virus, *Bacillus anthracis, Vibrio cholerae and Shiga Toxin Producing Enterrohaemorrhagic Escherichia coli, Brucellaabortus and Mycobacterium bovis/tuberculosis.* Outbreaks with these pathogens increases the exposure of the only 70,000 health care workers [12] and 4,500 veterinary and crop agricultural extension professionals estimated to be working in the country.

Whereas there is need for Uganda to establish strategies and mechanisms for ensuring safety from potential harms among practitioners and laboratory scientists and eliminating accidental release or unimpeded access and misapplication of pathogens of danger to public and environment, the necessary information is largely lacking. In response to the FAO recommendation [9] and the need to assess the status of awareness and existence of protocols, regulations, laws and policies on biosafety and biosecurity amongst relevant practitioners and scientists in public and private scientific establishments in the country this study was undertaken.

Materials and Methods

Study area

A total of 15 out of the 112 districts of Uganda [13] were selected from the four regions of the country. Eight of the surveyed districts were among those that had experienced outbreaks of highly infectious diseases such viral hemorrhagic fevers (Ebola and Marburg), cholera, hepatitis B and anthrax in the previous five years (UNOCHA Uganda, http://www.ugandaclusters.ug). The other seven were among the non-outbreak district category.

Study design

This cross-sectional survey was conducted for two months (June–July 2011). Study districts were selected using a two-stage cluster sampling method. The 112 districts of Uganda were divided into two: a cluster of districts that had reported at least one outbreak of highly infectious diseases during the previous five years (2005-2009) and a cluster comprising districts without such outbreaks. For each cluster, a sampling frame was developed. Using simple random sampling, one paper bearing a district name was picked at time (without replacement) until the sample size had been realized.

Study variables

The independent variables included profession, region and service sector: (1) Animal health teaching laboratories, (2) Animal health research laboratories, (3) Veterinary services, (4) Crop protection teaching laboratories, (5) Crop protection extension services, (6) Crop protection research, (7) Human health teaching laboratories, (8) Human health research laboratories, (9) Medical services, (10) Public hygiene services, and (11) Wildlife conservation and tourism services. The outcome variables were (1) knowledge about threat posed by dangerous pathogens, (2) knowledge on safety and national security, (3) knowledge on existence of a law providing for a list of dangerous biological agents and toxins and (4) perception about need for registration of highly pathogenic biological agents and dangerous biological toxins. Other variables were: (5) awareness of institutional implementation of the Biological Toxins and Weapons Convention and United Nations Resolution 1540, (6) existence of a policy or law addressing concerns of biosafety and biosecurity, (7) existence of measures to prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins, (8) record keeping and (9) existence of procedures on internal and international transfers of specimens. Also considered were: (10) existence of containers and procedures used for shipment of specimens, (11) measures that facilitate destruction or diversion to peaceful purposes of all pathogenic biological agents and toxins, (12) existence of measures to protect the population and the environment against highly pathogenic biological agents and dangerous biological toxins, (13) staff training in biosafety and biosecurity, (14) availability of ongoing initiative on the improvement of biosafety and biosecurity and (15) perception on existence of adequate national disease monitoring system.

Sample size

Since professionals working with institutions where biosafety and biosecurity measures are a requirement were more than 10,000 and based on 95% confidence level, sample size was determined using the formula for estimating sample size provided by Bartlett et al. [14]. A total of 385 respondents were interviewed during the study. Of these, 174 were from medical services in hospitals and 65 from human health research establishments. Other respondents were: 35 from agricultural extension services, 26 from veterinary services, 21 from crop research, 18 from public hygiene services, 17 for livestock health research and 11 were working in university training laboratories in human health. The other 11 respondents were from wildlife national park, conservation centre and wildlife training institute, and eight from university training laboratories for animal health. A total of 87 (22.6%) of the respondents were from central, 91 (23.6%) from eastern, 59 (15.3%) from northern and up to 148 (38.5%) were from western Uganda.

Type of respondents

In laboratories of biotechnology and microbiology, respondents included junior to senior scientists and technologists. In hospitals, respondents were medical superintendents/directors, medical officers/consultants and junior to senior cadres in the nursing and midwifery profession and junior to senior levels of laboratory technicians. Respondents in local governments were district and field veterinary officers and district and field agricultural officers. Other respondents comprised staff of district health offices such as district health officers, district health inspectors, district health educators and district health visitors. Also interviewed were conservation veterinarians, training instructors and technicians at a national park, wildlife training institute and wildlife education centre (zoo).

Data collection, management and analysis

Data were collected using a semi-structured questionnaire administered by an interviewer. All generated quantitative data was stored in EpiData and analysed using SPSS statistics software (version 20.0). Analysis was done at univariate, bivariate and multivariate levels for frequencies/proportions and existence of statistic relationships between predictor and outcome variables. Chi-square ($\chi 2$) and odds ratios (OR) were computed at $p<0.05$. Figures were drawn in Microsoft Excel.

Results

Regional, sector and professional distribution of respondents

The majority of the respondents were in medical services (45.2%, 174/385), while the least were from university animal health teaching laboratories (1.8%, 7/385) (Table 1).

Sector of assessment	Frequency	Percentage
University animal health teaching laboratories	7	1.8%
Veterinary services*	26	6.8%
Animal health research laboratories	17	4.4%
Crop protection extension services*	35	9.1%
Crop protection research laboratories	21	5.5%
University human health teaching laboratories	11	2.9%
Public health services*	18	4.7%
Medical services (hospitals)*	174	45.2%
Human health research laboratories	65	16.9%
Wildlife conservation and tourism (National Park and Zoo)*	11	2.9%
Total	385	100%

Table 1: Proportion of respondents per service sector. Key: *=sector from which disease report would originate

Among professions, nurses/midwives were the majority (31.2%, 120/385) and the minority (3.1%, 12/385) comprised veterinary conservationists (Figure 1).

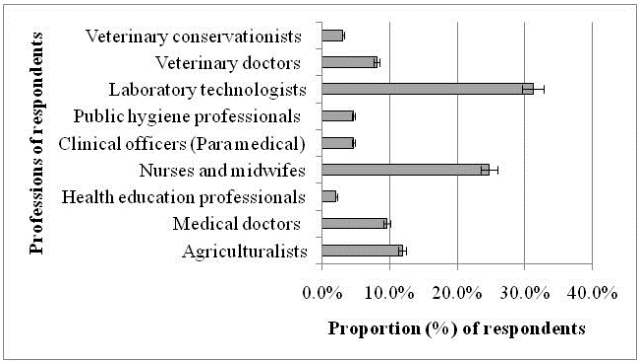

Figure 1: Proportional distribution of profession among respondents

Most (38.5%, 148/385) of the respondents were from the western region, followed by eastern (23.6%, 91/385) and central regions (22.6%, 87/385). The smallest proportion included professionals from the northern part of the country (15.3%, 59/385).

Threat posed by dangerous pathogens to public health

The study observed that almost all the respondents equally recognized that dangerous pathogens were a threat to public health. Minor variations existed among service sectors. Professionals in sectors including crop protection extension (97%, 34/35) and crop protection research (95%, 20/21) never perceived that dangerous pathogens could be a threat to biosafety and biosecurity in Uganda (Table 2).

Assessed sector	Proportion (%) of respondents per biosafety and biosecurity variable															
	PH	LoA	LLDB	RFR	BTWC	UN1540	PoL	MFP	REC	SPTR	SPHD	MFDD	TiBB	IIBB	DSM	Average
Animal health teaching	100	57	14	71	43	43	0	86	40	57	100	100	100	80	43	62
Veterinary services	100	65	42	77	0	0	63	46	58	27	54	50	42	58	27	47
Animal health research	100	71	0	77	53	53	41	59	29	41	100	65	41	88	6	55
Crop extension	97	51	34	80	17	17	60	31	37	54	49	49	40	50	46	48
Crop research	95	29	5	86	29	29	52	67	76	86	95	84	55	58	18	58
Human health teaching	100	73	46	64	0	0	36	55	73	46	72	64	56	46	55	52

Public health services	100	50	28	56	0	0	61	61	61	44	67	56	56	44	50	49
Medical services	99	59	27	77	16	16	36	57	59	35	66	61	47	57	52	51
Human health research	100	69	12	74	25	25	22	72	79	49	83	80	71	62	34	57
Wildlife conservation	100	63	36	55	9	9	45	64	36	55	45	82	27	64	73	51
Average	99	56	24	71	20	20	40	60	51	47	68	71	50	59	44	

Table 2: Proportional distribution of responses among assessed sector of scientific establishments. Key: PH=Knowledge of any list of agents based on threat to public health and safety and national security; LoA=List of agents based on threat to public health and safety and national security by any organization or country; LLDB=Law in Uganda that provides a list of dangerous biological agents and toxins; RFR= Opinion of the requirement in Uganda for the registration of highly pathogenic biological agents and dangerous biological toxins; BTWC= Existence of steps in implementation of the Biological Toxins and Weapons Convention; UN1540=Existence of steps in implementation of the UN Resolution 1540; PoL=Existence of policy or law in Uganda that adequately deals with national concerns on biosafety and biosecurity; pathogenic agents and biological toxins; MFP=Existence of measures to prevent or prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins; REC=Comprehensive recording of events and processes in this facility; SPTR=Specimens handled by approved carriers, in secure containers and packaged, labeled and shipment tracked, among others; SPHD=Measures in place to facilitate the destruction or diversion to peaceful purposes of all pathogenic biological agents and toxins; MFDD=Measures in place for destruction/diversion of biological agents/toxins, TiBB=Personnel trained in biosafety and biosecurity; IIBB=existence of initiatives to improve Biosafety and Biosecurity; DMS=Perception about existence of an adequate national disease monitoring system.

Variable of assessment		Proportions (%) of respondents		
		Central [N=92]	Eastern [N=88]	Northern [N=59]
Think dangerous organisms are a threat to Biosecurity	100	100	96.6	99.5
Claimed to have knowledge of list of agents	55.4	59.1	55.9	36.3
A law for a list of dangerous biological agents exists	6.5	21.6	37.3	32.2
A need to register highly pathogenic agents exists	81.5	71.6	79.7	71.2
Steps for implementation of BTWC exists	37	22.7	10.2	5.5
Steps for implementation of UN1540 exists	37	22.7	10.2	5.5
Aware of a policy/law addressing Biosafety/ Biosecurity	29.3	42	42.4	42.5
Measures to prevent stockpiling of agents/toxins exist	67.4	55.7	62.7	51.4
There is comprehensive recording of events and processes	69.6	65.9	59.3	48.6
Specimen transfers are done with permits and certificates	48.9	70.5	44.1	41.1
Specimen are handled by approved containers and labeled	94.6	62.5	67.8	59.6
Have measures to destroy/ divert biological agents/ toxins	73.9	47.7	42.4	59.6
Measures to protect public from agents and toxins exist	88	52.3	55.9	63
Staff is relatively trained in Biosafety and Biosecurity	60.9	48.9	45.8	46.6
Initiatives to improve Biosafety and Biosecurity exist	66.3	55.7	54.2	56.2
Uganda has adequate disease monitoring system	26.1	36.4	54.2	53.4

Table 3: Proportional distribution of respondents with positive responses

Although regional variations were minor (Table 3), region was a predictor for this perception. There was an association (χ^2=38.2) between sector and the perception that dangerous pathogens were a threat to public health. Professionals in veterinary services sector were 9.0 times more likely to hold the perception (OR=19, 95% CI: 1.54–228) than their colleagues working in animal health teaching laboratories (Table 4).

Outcome variable	Predictor sector	OR	[95% CI]	P=value
PH	Veterinary services	19	1.54-228	0.021*
LLDB	Animal health research laboratories	5.4	1.26-23.6	0.023*
	Crop protection research laboratories	11	2.13-57.6	0.004**
	Human health research laboratories	2.8	1.11-7.22	0.030*
BTWC	Veterinary services	12	1.88-77.7	0.009*
	Animal health research laboratories	8.9	2.35-33.4	0.001**
	Crop protection research laboratories	29	6.44-130	0.000**
	Human health research laboratories	5.6	2.06-15.4	0.001**
UN1540	Veterinary services	0.1	0.03-0.52	0.005*
	Public health services	0.2	0.04-0.82	0.027*
	Medical services	0.3	0.10-0.64	0.004**
	Human health research laboratories	0.2	0.06-0.54	0.002**
MFP	Animal health research laboratories	0.2	0.05-0.87	0.032*
	Crop protection extension	0.2	0.05-0.60	0.006*
RECORDS	Crop protection extension	0.4	0.21-0.91	0.027*
	Human health research	2	1.01-4.13	0.027*
SPTR	Veterinary services	0.2	0.06-0.43	0.000**
	Crop protection extension	0.3	0.07-0.94	0.029*
	Medical services	0.4	0.20-0.74	0.004**
SPHD	Veterinary services	0.1	0.04-0.32	0.000**
	Crop protection extension	0.1	0.04-0.29	0.000**
	Public health services	0.2	0.06-0.67	0.010*
	Medical services	0.2	0.10-0.57	0.001**
	Wildlife conservation and tourism services	0.1	0.02-0.51	0.006*
DSM	Crop protection extension	4	1.05-15.4	0.043*
	Human health teaching	5.7	1.15-28.3	0.033*
	Public health services	5.4	1.26-23.9	0.025*
	Medical services	7	2.25-21.9	0.001**
	Wildlife conservation and tourism services	9.5	1.27-71.0	0.028*

Table 4: Predictor sector for knowledge and perceptions on existence of laws, regulation and practices affecting biosafety and biosecurity in Uganda.Key: OR=Odds ratio; CI=Confidence Interval; *Significant at p<0.05; **=Significant at p<0.01

Knowledge of a list of agents that are a threat

No significant difference in knowledge of existence of any list of agents based on threat to public health/safety and national security was observed among professionals in the study service sectors. Knowledge about this variable was nonetheless much lower among respondents in crop protection research (29%, 6/21) compared to counterparts in the other sectors (Table 2). While the majority of the interviewed professionals in all the other three regions claimed to have this knowledge (Table 3), only 36.3% of respondents in western region held the same view. No association existed between this variable and profession, sector or region.

Law providing for a list of dangerous biological agents and toxins

The proportions of respondents holding the notion that there was a law providing for a list of dangerous biological agents and toxins were very low. The highest proportion with this view was in northern Uganda (37.3%, 22/59), while the smallest (6.5%, 6/92) was for colleagues in central region (Table 3). There was a significant relationship (χ^2=30.8) between sector and the perception that such a law existed. Among other relationships, professionals working in crop protection research laboratories were particularly much more likely to perceive that the law existed (OR=11, 95% CI: 2.13-57.6, p<0.01) compared to colleagues in medical services (Table 4). Equally, profession was a predictor (χ^2=15.0) for this variable. Professionals in public hygiene services were 70% less likely to consider that a law providing for a list of dangerous pathogens and toxins was available (OR=0.3, 95% CI: 0.08-0.84) than clinical officers. In a similar association, all the other three regions were less likely to accept existence of a national policy or law serving that purpose than those in central region (Table 6).

Need for registration of dangerous biological agents and toxins

With exception of professionals in wildlife conservation and tourism sector, the majority of respondents in almost all professions, sectors and regions indicated the need for registration of dangerous biological agents and toxins. A significant relationship (χ^2=7.69) existed between profession and the opinion about the necessity for registration of dangerous biological agents and toxins. Clinical officers had increased odds for the opinion (OR=8.3, 95% CI: 1.25-55.4) compared to health education professionals (Table 5).

Assessment variable	Predictor profession	OR	[95% CI]	P=value
LLDB	Public health professionals	0.3	0.08-0.84	0.025*
RFR	Clinical officers	8.3	1.25-55.4	0.028*
BTWC	Veterinary doctors	2.4	1.09-5.49	0.031*
UN1540	Agriculturalists	2.4	1.10-5.46	0.029*
PoL	Agriculturalists	3.3	1.05-10.1	0.041*
MFP	Agriculturalists	0.5	0.24-0.94	0.031*
MFDD	Public health professionals	0.3	0.10-1.00	0.042*
	Laboratory technologists	2.4	1.11-4.99	0.026*
IIBB	Laboratory technologists	0.6	0.32-0.98	0.042*
DMS	Veterinary doctors	0.2	0.05-0.94	0.042*

Table 5: Predictor professional sectors for the assessment variables. Key: OR=Odds ration; *=Significant at p<0.05; LLDB=Law in Uganda that provides a list of dangerous biological agents and toxins; RFR=Opinion of the requirement in Uganda for the registration of highly pathogenic biological agents and dangerous biological toxins; BTWC=Existence of steps in implementation of the Biological Toxins and Weapons Convention; UN1540=Existence of steps in implementation of the UN Resolution 1540; MFP=Existence of measures to prevent or prohibit production, stockpiling, retention or unimpeded access; PoL=Existence of policy or law in Uganda that adequately deals with national concerns on biosafety and biosecurity; pathogenic agents and biological toxins; MFP= Existence of measures to prevent or prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins; MFDD=Existence of measures in place for destruction/ diversion of biological agents/toxins; IIBB=existence of initiatives to improve Biosafety and Biosecurity; DMS=Perception about existence of an adequate national disease monitoring system.

Implementation of the BWTC and United Nations Resolution 1540

All respondents were ignorant about the Biological Toxins and Weapons Convention (BTWC) and UN resolution 1540. However, when the concept and provisions of each of the two laws were explained, some respondents indicated that their institutions had in place some steps to implement the two laws. While all sectors had some proportions of respondents indicating existence of such steps, none among the professionals in veterinary services, human health teaching laboratories and public hygiene services believed so (Table 2). Regional comparison revealed that the highest proportion for each of the two laws was 37.0% (34/92) for institutions in central region (Table 3). Profession was associated (χ^2=67.9) with these two variables. The relationships between profession and the existence of steps to implement the two laws are shown in Table 4. In Table 5, the significant relationships (χ^2=24.1 and χ^2=9.91) between profession and the perceptions about institutional implementation of the two laws are shown.

Policy addressing concerns of biosafety and biosecurity

The perceptions of professionals in the different sectors of existence of a policy addressing concerns of biosafety and biosecurity significantly varied. None among the respondents in animal health teaching laboratories believed that such a policy ever existed. On the contrary, up to 62% (16/26) of colleagues in veterinary services, 64% (7/11) in wildlife conservation and tourism, 64% (7/11) in public health services and 60% (21/35) in crop extension indicated otherwise (Table 2). Similar belief was held by 29.3% (27/92) of professionals in

central and fairly higher proportions of colleagues in all the other three regions (Table 3). In a significant relationship (χ^2=7.32) between profession and this variable, agriculturalists had increased odds of being associated with the opinion of existence of the policy (OR=3.3, 95% CI: 1.05-10.1) than public hygiene professionals (Table 4). In comparison with central region, respondents in all the other three regions were less likely to hold the opinion that such a policy existed (Table 6).

Prohibition of production, stockpiling, retention of pathogenic agents and toxins

Although the majority of respondents in all the sectors asserted that some steps aimed at preventing or prohibiting production, stockpiling, retention of pathogenic agents and toxins existed in their institutions, only 46% (12/26) of professionals in veterinary services and 31% (11/35) of colleagues in crop extension believed otherwise (Table 2). Profession significantly influenced (χ^2=49.0) the opinion that institutional measures were in place to prevent or prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins. Like colleagues in the crop protection extension, professionals in animal health research laboratories had reduced odds of this opinion (OR=0.2, 95% CI: 0.05-0.87) in comparison with their counterparts in public hygiene services. Comparatively, the professionals in northern region were more likely to believe that the institutional measures were available (OR=2.4, 95% CI: 1.18–4.76) compared to colleagues in eastern (Table 6).

Assessed variable	Predictor regions											
	Central			Eastern			Northern			Western		
	OR	CI	p-value	OR	CI	p-value	OR	CI	p-value	OR	CI	p-value
PH	0	0.01-0.10	0.000**	0.1	0.03-0.30	0.000**	0.1	0.03- 0.26	0.000**	Region of reference (RC)		
LLDB	Region of reference (RC)			0.2	0.11-0.47	0.000**	0.3	0.14-0.68	0.004*	0.1	0.05-0.18	0.000**
PoL				0.5	0.28-1.02	0.061	0.3	0.16-0.61	0.001**	0.3	0.14-0.45	0.000**
MFP	2.5	1.32-4.68	0.005*	Region of reference (RC)			2.4	1.18-4.76	0.015*	1	0.55-1.64	0.865
REC	Region of reference (RC)			0.5	0.23-1.17	0.115	0.4	0.16-0.86	0.021*	0.2	0.07-0.29	0.000**
SPTR	23	0.75-59.5	0.000**	2.6	1.34-4.11	0.003**	2.2	1.19-3.99	0.011*	Region of reference (RC)		
SPHD	Region of reference (RC)			0.1	0.04-0.28	0.000**	0.1	0.03 -0.26	0.000**	0.1	0.03-0.22	0.000**
MFDD	41	9.42-184	0.000**	1.5	0.76-2.88	0.245	Region of reference (RC)			1.5	0.82-2.69	0.191
TiBB	Region of reference (RC)			0.3	0.17-0.65	0.001*	0.4	0.17-0.71	0.004*	0.3	0.16-0.51	0.000**

Table 6: Predictor regions for the assessment variables. Key: OR=Odds ratio; CI=Confidence Interval; *Significant at p<0.05; **=Significant at p<0.01; RC=Reference category

Record keeping

Perception about consistent record keeping varied among respondents in the different study sectors. The highest proportion of respondents with this opinion were in human health research and teaching laboratories, in which 79% (51/65) and 73% (8/11) of the workers, respectively indicated records were kept about every event or activity undertaken (Table 2). While the majority of respondents in the other three regions indicated existence of comprehensive recording of events and processes (Table 3), the proportion of respondents with the same view in western region was lower (48.6%, 71/146). Compared to central, all the three other regions had reduced odds for the opinion of record keeping in their institutions (Table 6).

Procedures on internal and international transfers of specimens

The study observed significant proportional variations in responses regarding the use of permits, end-use certificates, and detection equipment in internal and international transfers of specimens in the surveyed scientific facilities. While 86% (18/21) respondents working in crop research laboratories confirmed use of the stated procedures, the proportions of colleagues holding the same opinion in veterinary services was very low (27%, 7/26). Although the professionals in eastern region indicating existence of procedures on internal and international transfers of specimens were nearly three quarters (70.5% (62/88), counterparts holding the same view in all the other three regions were a minority (Table 3). A significant relationship (χ^2=32.0) existed between sector and perception about existence of procedures on specimen transfer in the study establishments. Professionals in veterinary services, crop protection extension and medical services sectors were less likely to be associated with institutions practicing these procedures compared to colleagues in human health research laboratories (Table 4). Markedly, institutions in central region were 23 times more likely to use these procedures (OR=23, 95% 0.75-59.5, p<0.01) than those in northern Uganda (Table 6).

Containers and procedures used for shipment of specimens

Striking variations existed among respondents' opinions in regard to use of approved carriers, secure containers and packages, labeling and tracking of specimens during handling and shipment. While all (100%, 7/7) colleagues in animal health teaching and animal health research (100%, 17/17) reported that these procedures were a regular phenomenon in their institutions, a minority of colleagues in crop extension (49%, 17/35) and wildlife conservation (45%, 5/11) had this

notion (Table 2). No proportional variation was observed among regions (Table 3), though a bivariate analysis revealed significant relationship (χ^2=32.1) between sector and this variable. In the relationship, up to five sectors were less likely to hold the opinion that their institutions used approved carriers, secure containers and packages, labeled and tracked specimens during sample handling and shipment compared to professionals in human health research laboratories (Table 4). Eastern, northern and western were 80%-90% less likely to hold the notion compared to their counterparts in central region (Table 6).

Measures to facilitate destruction or diversion of pathogenic agents and toxins

Although the majority of respondents of all the sectors indicated that institutional measures were in place to facilitate the destruction or diversion to peaceful purposes of all pathogenic biological agents and toxins, the proportions of colleagues with this view among those in veterinary services and crop extension were only 50% (13/26) and 49% (17/35), respectively (Table 2). Sector was a predictor (χ^2=29.2) for the opinion of existence of procedures for destruction or diversion measures. While public hygiene professionals were less likely to hold the view that such measures existed, laboratory technologists were 2.4 times more likely to be associated with the perception (OR=2.4, 95% CI: 1.11-4.99) than agriculturalists (Table 5). Comparatively, central region was strongly associated with the same opinion (OR=41.6, 95%; CI=9.42-184, p<0.01) compared with counterparts in northern (Table 6).

Staff training in biosafety and biosecurity

The study observed noticeable disparity in training in biosafety and biosecurity among professionals in sampled institutions. Whereas 100% (7/7) of professionals in animal health teaching laboratories had undergone the training, only 41% (7/17) of those in animal health research laboratories had been trained (Table 2). Regionally, only central had the majority (60.9%) of the staff trained (Table 3). All the other three regions were 60%-70% less likely to be associated with training in biosafety and biosecurity compared to the central region (Table 6).

Initiatives on improvement of biosafety and biosecurity

Although the majority of respondents in most sectors believed that some institutional initiatives were in place to improve biosafety and biosecurity, smaller proportions among human health teaching laboratories (46%, 5/11) and public hygiene services (44%, 8/18) believed so (Table 2). Profession had influence (χ^2=5.66) on this opinion, with laboratory technologists being 40% less likely to hold this view (OR=0.6, 95% CI: 0.32-0.98) compared to nurses/midwives. No association was observed between region or sector and the opinion of existence of initiatives to improve biosafety and biosecurity.

Existence of adequate national disease monitoring system

The view that Uganda had an adequate disease monitoring system differed among sectors, varying from as low as 6% (1/17) among professionals in animal health research to as high as 73% (8/11) among colleagues in wildlife conservation and tourism (Table 2). This opinion was very scarce in central (26.1%) and eastern (36.4%) compared to the other two regions (Table 3). The study observed a significant relationship (χ^2=20.1) between sector and perceptions about existence of adequate disease monitoring system in Uganda. Up to five sectors had increased odds for the notion that an adequate monitoring system existed compared to veterinary services sector (Table 4). Profession was a predictor (χ^2=17.9) for this opinion. Unlike all other professions, veterinary doctors were less likely to believe that the available national disease monitoring system was adequate (OR=0.2, 95% CI: 0.05-0.94) compared to public health professionals.

Discussion

The fundamental assumption is that the unintended release of pathogenic or genetically modified organisms might exert major harm or pose non-quantifiable risks to human beings and the environment [15]. Additionally, biosafety principles, technologies and practices help prevent unintentional exposure to pathogens and toxins, or their accidental release [16]. With these laboratory measures and modern biosafety legislation, all pathogenic or genetically modified organisms can be effectively blocked from release from a facility during handling [15]. Measures of biosecurity are in addition expected to ensure protection, control and accountability for valuable biological materials within laboratories, in order to prevent their unauthorized access, loss, theft and dual-use (misuse, diversion or intentional release) [1]. Biosecurity always requires a strategic and integrated approach that encompasses the policy and regulatory frameworks for analyzing and managing relevant risks to human, animal and plant life and health, and associated risks to the environment [17].

While the present study mainly observed similarities, differences in knowledge, opinions and practices or measures among professionals and institutions in the different service sectors and regions existed. The observation that almost all respondents recognized the threat posed by dangerous pathogens to the safety and biosecurity of Uganda's populace was good. It exhibited a good level of knowledge. The proportion was higher than 46% reported in other developing states [18].

Mainly professions in research laboratories held the notion that a list of dangerous organisms existed. Whether the list exist or not, the uncertainty among most professionals about the existence of such a list provided additional evidence about the perception that there is need to catalogue the scientific and medical laboratories and the organisms they work with in the country [7].

There was evidence of confusion among respondents about whether or not there was a law in Uganda that provided for a list of dangerous biological agents and toxins. The majority particularly indicated the law never existed. The fact that the majority of the respondents were either not confident about the existence or reaffirmed that such a law was absent exhibited extra substance about the lack of policy or law that adequately deals with national concerns on biosafety and biosecurity. With the exception of scientists and technicians in agricultural biotechnology whose work was covered by the existing Biotechnology and Biosafety Bill [8], the opinion that there was no such law or policy was generally expected among professionals in the biomedical fields. Concern about lack of policy or law to support biosafety and biosecurity was reported in earlier studies in Uganda [6,7].

Since it was revealed that most institutions lacked measures to protect the population and environment against highly pathogenic biological agents and dangerous biological toxins, this proved lack of adequate biosafety and biosecurity measures. The observation meant that a high level of exposure to hazardous agents could not be ruled

out. Neglect of containment of microorganisms to prevent unintended release [15] is a great risk. Such a situation is worse in a country like Uganda, which often experiences outbreaks of some of the highly infectious zoonotic diseases such as Anthrax, Hepatitis B and E, Ebola and Marburg whose samples are supposed to be handled under biosafety level IV containment facilities and procedures [19,20], but are often first handled at much lower level facilities in the country.

The observation that the majority of the surveyed institutions lacked steps to implement measures aimed at preventing and prohibiting accumulation and misuse of dangerous pathogens contradicted the BTWC [21] and UN resolution 1540. This was an indication of high level of ignorance about the convention and resolution or a sign of irresponsibility on part of the workers or their supervisors, regardless of sector, profession or region. This reflected an increased risk of access to dangerous pathogens. This result not only provided additional evidence of non-compliance predominantly observed for countries located in Africa and Central America [22], but also showed that dual-use with the frequent outbreak of highly dangerous pathogens was quite likely if preventive interventions were not developed and applied in time.

The fact that existence of measures to prevent or prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins was only limited to about a half of the surveyed institutions was a sign of poor biosecurity. This corroborated earlier reports that many developing countries have inadequate biosecurity capacity [23]. This omission also meant that Uganda had not adequately addressed Article II of the 1972 convention on the prohibition of the development, production and stockpiling of bacteriological (biological) and toxin weapons and their destruction. This Article equally requires that every signatory state undertakes to destroy, or divert to peaceful purposes, all agents, toxins, weapons, equipment and means of delivery specified in Article I of the convention, which are in its possession or under its jurisdiction or control. Omission of measures to prevent or prohibit production, stockpiling, retention or unimpeded access to pathogenic agents and biological toxins can increase the risk of dual-use research on dangerous pathogens.

Whilst it is a requirement that events, procedures followed and results obtained are properly and promptly recorded and records adequately kept, a significant proportion of the surveyed institutions lacked a comprehensive system of record keeping. This reflected a very big loophole in implementation of proper biosafety and biosecurity. In such faulting institutions, tracking of events and biological materials handled, in terms of category and quantity, may prove impractical. Ensuring biosecurity in such a situation is, but only a dream. Inadequate record keeping can make implementation of accountability of dangerous pathogens very difficult in laboratories and may predispose to dual-use research on dangerous pathogens.

Although it is highly recommended that internal and international transfers of specimens be done through permits, end-use certificates, and/or detection equipment [20], it was observed that the majority of institutions did not apply such measures. This easily compromises biosafety and biosecurity. This was worse due to the fact that a significant proportion of respondents indicated that their institutions were handling specimens without approved carriers, secure containers and packaged, labelling and tracking of shipment. Therefore, biosafety and biosecurity could still be regarded wanting [19]. Failure to observe recommended procedures in specimen transfer can easily predispose to dual-use research.

The observation that most of the respondents worked in institutions that lacked measures to facilitate the destruction/diversion to peaceful purpose was a sign of lapses in biosecurity. Matching this observation with the result that there was misuse of personal protective equipment by some personnel mainly in upcountry laboratories and hospitals was additional confirmation that good laboratory practice worsen as the distance increases from capital to peripheral laboratories in many developing countries [24]. Whatever the interpretation of these findings, lack of regulation, management and control of release of living pathogenic and modified organisms resulting from laboratory manipulations can easily culminate into adverse public and environmental impacts [25], either to accidental exposure or dual-use research on dangerous organisms.

Whereas adequate knowledge of personnel handling sensitive biological materials is essential for effective implementation of biosafety and biosecurity measures, most workers were not adequately trained. Inadequate training affects efforts to improve biosafety and biosecurity in developing countries [24]. The fact that the veterinary sector showed the greatest inadequacy was particularly risky since professionals in this sector could easily be exposed to zoonotic pathogens at farm level during physical examination or sample collection. Although the proportion of non-trained personnel was fairly lower than what is reported in some Asian countries [26] including Pakistan [18], it is still not a sign of adequate safety for a country still experiencing emerging zoonotic diseases such as Ebola and Murgab, which may require that all workers are adequately trained in biosafety and biosecurity. This result provided further evidence that lack of training in safety remains one of the challenges in developing countries around the world [24; Black, http://www.ocimum-biosecurity.eu/Biosecurity.htm). This situation was not surprising because many laboratories in developing countries including Uganda, lack designated Safety Officers, safety guidelines and standard operating procedures [24], which makes enforcement of biosafety regulations and procedures extremely difficult. Lack of knowledge in biosafety and biosecurity management may increase the risk of un-intentional exposure to or dual-use research on dangerous pathogens.

Although an efficient disease monitoring system of either humans or animals is essential in early detection of diseases, including those of public health or economic implications, nearly half of the respondents held the opinion that an adequate disease monitoring system never existed in Uganda. If incorporated within the national animal or human infrastructure, such a system enhances the capacity to respond promptly to the detection of unusual mortality [27]. Surveillance and monitoring of disease outbreaks are particularly relevant current trends of rapid human and animal translocation when the contact between domestic and wild animals is close and the threat of a bioterrorism event is very real [27]. The perception by most professionals, that the national disease monitoring system in public health, animal health or crop protection broad sectors was inadequate, could be accurate. It might be one of the reasons why Uganda has a high frequency of disease outbreaks due to emerging infectious disease pathogens in the recent past (UNOCHA Uganda, http://www.ugandaclusters.ug).

The current study has demonstrated that scientific establishments in Uganda are largely characterized by poor biosafety and biosecurity. Generally, lack of adequate capacity in biosafety and biosecurity jeopardizes the ability of a country to protect the health and well-being of its population, animals, and plants. As a result it becomes very

difficult for a state to ensure protection against risks to the environment, threats to economic interests and trade, and compromises the ability of a country to meet international legal commitments [23]. Consequences of poor biosafety are even worse since Uganda still has only approximately 1.8 health care workers per 1,000 populations compared to the ratio of 2.3/1,000 recommended by World Health Organization [12]. Consequences of poor biosecurity could also be worse due to increased global terrorism, with limited capacity in national biodefense. In a 2008 East African international workshop for promoting biosafety and biosecurity within the life sciences, it was emphasized that African countries should avoid the emergence of bioterrorism on the continent, and protect against accidents and spillage of pathogens into the environment through improving laboratory safety. It was specifically suggested that the highest risk lied within the inability of any African country to prevent their laboratories from inadvertently releasing into the environment viral or bacterial pathogens being used for research [28]. There is no evidence that a similar study has been undertaken within the East African regions. The results from this study could therefore inform the situation within the region. The Animal Diseases Act; The Public Health Act; The Plant Protection Act; The Penal Code Act; The National Environment Act; The Occupation Safety and Health Act; The Anti-Terrorism and The Occupational Safety and Health Act, among others, are some of the national legal frameworks that have a bearing on biosecurity. These are however weak and non-specific.

It is essential that more specific studies be conducted per sector, profession, and region, to determine the efficiency and effectiveness of the procedures and measures based on the prevailing situation. It would be vital that stakeholders including, but not limited to, professionals categorized in this study, and the defense and police forces are sensitized of the international laws and their requirements and the need for formulation and implementation of national and institutional policies and laws on biosecurity. Multi-stakeholder and multi-disciplinary consultations and capacity building should make critical ingredients of every process and framework.

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