A Survey of Biosafety and Biosecurity Practices in the United States Army Medical Research Unit-Kenya (USAMRU-K)

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Abstract

USAMRU-K Department of Emerging Infectious Diseases (DEID) is a program consisting of eight facilities (laboratories) that are centrally administered. It has instituted safety regulations in the past 5 years under specific safety standard operating procedures (SOPs) with a goal to minimize work-related risks, injuries, or illnesses to laboratory and clinical workers by ensuring that they have the recommended training, information, support, and equipment to work safely. The programs (Influenza [FLU], Acute Febrile Illness [AFI], Arthropod-borne Virus, Enterics, Malaria Drug Resistance, Malaria Diagnostic Center, and Entomology) respond to different health problems including emerging and re-emerging diseases, some of which could result from select agents such as Ebola virus, Marburg virus, West Nile virus, Africa Swine Fever virus, Bacillus anthracis*,* Yersinia pestis*, and H1N1. The safety regulations are meant to enhance awareness through education and to minimize or prohibit possession, use, or transfer of dangerous microorganisms to safeguard the employees, environment, and communities from exposure. In Kenya the available government safety regulations cover only genetically modified organisms (GMO), and no data are available in most government laboratories concerning occupational health, biosafety, and biosecurity when working with such agents. In the laboratories at USAMRU-K, no data existed before these regulations were instituted. For the USAMRU-K to address these biorisk and occupational health gaps, a Safety Officer was designated and trained and embarked on vigorously training all employees and carrying out biannual audits and surprise audits in all the USAMRU-K laboratories to bring them to acceptable biosafety/biosecurity and occupational health standards. The laboratories were assessed in occupational health, safety training and management, chemical safety, biorisk management, housekeeping, shipping dangerous goods, and data management using a structured questionnaire. The audits revealed that employees are actively engaged in research and patient recruitment with a wide variety of biological agents and disease presentations. Moreover, analysis of the biosafety and biosecurity data revealed biosafety was more prevalent than biosecurity, that simple practices and techniques predominated, and that perceptions of risk varied across the facilities as they deal with different biological agents. These findings provided unique insight into the variety of microorganisms studied in various USAMRU-K laboratories and uncovered a consistent weakness occupational health because vaccination was sporadic and no follow-up was conducted to determine if protection was achieved. Booster vaccinations were not documented.*

USAMRU-K improved in biorisk management and occupational health 2 years after implementation of the regulations. USAMRU-K is now considered a regional reference point of consultancy in safety regulations from which other institutions from Kenya (Ministry of Health, Agriculture, and Tourism) and other countries (Uganda, Tanzania, Southern Sudan, and Cameroon) are learning. Since research facilities are located in close proximity to communities in Kenya, these findings indicated a potentially significant risk; therefore, future actions are warranted to improve the safe and secure handling of biological agents in the country to prevent accidental escape or release to the community.

Keywords

Biosafety Survey, Biosecurity Survey, Occupational Health, Kenya, and Program Evaluation

Introduction

There are many diseases in Kenya and the region at-large. The most common that are considered endemic are diarrhea (due to different bacteria, protozoa, and virus), anthrax, malaria, viral hemorrhagic fevers (VHF), influenza, leptospirosis, and acute febrile illnesses. Some are emerging while others are considered re-emerging. All have an impact on the safety of an employee and the environment as a whole. Occupational health, biosafety, and biosecurity are fundamental practices that must be consistently implemented and enforced in all active bioscience research and clinical laboratories. As critical as these concepts are to the health and well-being of employees as well as the environment, biosafety and biosecurity awareness is lacking in some countries in the region. Moreover, confusion with basic terminology exists as multiple definitions of biosafety and biosecurity are in circulation, and the terms are often used interchangeably. For example, "biosafety" often refers to the protection of the environment from genetically modified organisms; in animal industries, "biosecurity" refers to the protection of animals from microbial contamination. In regions that do recognize biosafety within a laboratory framework, biosecurity may not be independently recognized, or it is interpreted to mean the same as biosafety in French-speaking nations. Since 1983 the World Health Organization (WHO) has been instrumental in promoting the necessity of laboratory safety, providing international guidance on basic biological safety and developing national codes of practice for the safe handling of pathogenic microorganisms in a laboratory setting (WHO, 2004). WHO and *Biosafety in Microbiological and Biomedical Laboratories* (*BMBL*) define laboratory biosafety

as "the containment principles, technologies and practices that are implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release" (U.S. HHS, 2009; WHO, 2004). In 2004, WHO defined laboratory biosecurity as "institutional and personal security measures designed to prevent the loss, theft, misuse, diversion or intentional release of pathogens and toxins" (WHO, 2004). The American Biological Safety Association (ABSA, www.absa.org) and the European Biosafety Association (EBSA, www.ebsaweb.eu) are two other internationally recognized professional organizations that have been fundamental in establishing laboratory biosafety and biosecurity programs around the world, and they each define biosafety and biosecurity similarly to the WHO definitions. In addition, the Africa Biological Safety Association (AfBSA, www.afbsa.org), that was instituted 3 years ago has similar definitions and has also made great contributions in the African region through its conferences and workshops. In the past decade, these and other organizations have contributed to a greater knowledge and commitment to laboratory biosafety and biosecurity in the global scientific community. Amerithrax (the case name referring to the 2001 *Bacillus anthracis* attacks in the U.S.) and other recent laboratory accidents and releases have alerted governments to the importance of biosafety and biosecurity, provoking the establishment of major economic and political initiatives to minimize the consequences of such biological risks. The United States has been a global leader in promoting laboratory biosafety and biosecurity by enacting laws to regulate the possession, use, and/or transfer of select agents, with violations carrying criminal and civil penalties as demonstrated in two key U.S. laws: the USA PATRIOT Act and the Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Many other countries such as Britain and Australia have enacted similar national regulations. Nevertheless, even with some of the most stringent safety and security safeguards in place, since 2003 American laboratories handling dangerous microorganisms and toxins have experienced more than 100 accidents involving such high-risk agents as *Bacillus anthracis*, highly pathogenic avian influenza virus A (H5N1), Monkeypox virus, and *Yersinia pestis*, and the number is increasing; biosecurity infractions are also numerous (Kaiser, 2007; MSNBC, 2007; Ramshaw, 2007). This could be due to active, increased surveillance.

While some information is available from the United States and other developed countries such as Britain, Russia, and Australia, very little is known about how developing and underdeveloped nations' laboratories are implementing biosafety and biosecurity. Also very little data are openly available that address biosafety or biosecurity incidents around the world, especially in developing and underdeveloped countries. To successfully audit and assess the state of laboratory biosafety and biosecurity and occupational health, the USAMRU-K Safety Officer used a structured questionnaire in the biannual audits to capture information that related to: 1) the level of awareness and understanding of biological risks in laboratories; 2) the types of dangerous agents actively studied; 3) the types and practices of safety and security needed to maintain laboratories; and 4) the level of safety training.

Method

Audits

The eight laboratories under USAMRU-K were audited via a questionnaire that covered safety training, occupational health programs, infectious organisms and/or toxins handled, data security, microorganism transfer within and outside the country, biosafety practices, and biosecurity practices. The laboratories' work included basic science, drug discovery, routine surveillance, response, and vaccine trials. Different employees were interviewed during the process. The checklist (questionnaire) was designed by the USAMRU-K Safety Officer for all laboratories in the unit and was administered from 2008-2012. The findings from each laboratory were analyzed and the report generated recommendations for improvement.

Results

Trainings

Before entering the program, safety training was mandatory. It consisted of training regarding bloodborne pathogens and infection control, chemical hygiene and inventory, use of personal protective equipment (PPE) (donning, doffing, and selection), fire safety and evacuation, general laboratory safety, and hand hygiene before assumption of assigned duties. Additional training was laboratory-specific and included biosafety levels, biological safety cabinets, laminar flow hoods, autoclaves and fume hood use and maintenance, occupational health, risk assessment and mitigation, waste management, packaging, categorization and shipping of infectious substances, and laboratory emergency procedures. All (eight) laboratories were involved. Two hundred and twenty three personnel (technicians, clinicians, and custodians) were trained. Success of the training was measured by a pass mark of 80% and implementation of biosafety/biosecurity practices at work. All employees passed the training and followed regulations as trained. Every employee who was trained, examined, and passed was awarded a certificate with a copy filed in his/her training folder. Drivers who ship samples from the field (site clinics) to the central laboratories were trained on hand hygiene, types of possible pathogens to which they could be exposed, and how proper packaging should look. The purpose of this training was to educate them about what they were carrying and the dangers involved so that they would take precautions for their safety.

Infectious Microorganisms or Toxins Handled

The laboratories cover different fields, such as virology (AFI, VHF, FLU), microbiology (sexually transmitted

infections [STI], Enterics), and parasitology (Malaria drug resistance), and perform research on a wide range of organisms, including work in the fields of bacteriology, virology, entomology, and drug discovery. The diverse list is representative of the country's diseases and public health threats. The most frequently studied agents include *Escherichia coli* pathotypes, *Salmonella spp*, *Shigella spp*, *Vibrio cholera*, *Campylobacter spp*, rotavirus, influenza viruses (influenza A, B, and pandemic), Marburg virus, O'nyong-nyong virus, Rift Valley fever virus, norovirus, respiratory syncytial virus, corona virus excluding SARS, enteroviruses, rhino virus, *Plasmodium spp*, Lassa fever virus, and Human immunodeficiency virus (HIV). Toxins were studied less often and include enterotoxigenic, enteropathogenic, enteroaggregative and enteroinvasive, and cholera A and B toxins.

Occupational Health Programs

Prior to 2009, only 13 out of 230 employees had been vaccinated. However, these 13 employees did not have any documentation for proof of their vaccinations. After implementation of the safety program, all applicable vaccinations with full doses were administered, with documentation mandatory and follow-up boosters administered when necessary. These vaccinations included Hepatitis B, Yellow fever, and rabies. All employees working with human body fluids received a full-dose HBV vaccination. Those working in viral hemorrhagic fever and acute febrile illness laboratories received Yellow fever vaccine in addition to HBV. Those working in entomology, due to their field work, received rabies vaccine in addition to Yellow fever due to the high chance of encountering stray dogs and the risk of being bitten.

Biosafety Practices

Personal protective equipment (PPE) was the most consistently used biosafety practice in all programs (Table 1).

Gloves, gowns, and lab coats were the most common PPE and were routinely worn 100% of the time when work was in progress. Face shields and goggles were not common and used less frequently. Biosafety cabinets (BSCs) and an autoclave within the laboratory were common in all laboratories. The BSCs were maintained based on the manufacturer's recommendations. More sophisticated biosafety practices, such as the ability to monitor people using closed circuit television (CCTV), were not present until the year 2009 when CCTVs had been installed in four out of the eight laboratories. Two-way communication devices were lacking in all programs. Other measures, such as building ventilation systems and effluent waste decontamination systems, were present in all laboratories.

A review of biosafety level practices revealed two significant findings. First, all laboratories were identified as BSL-2 and enhanced BSL-2 containment settings (Table 1), and this was consistent across the unit. Two out of eight laboratories were BSL-2 enhanced. There were no BSL-3 containment laboratories in USAMRU-K. Any agent that required BSL-3 or BSL-4 containment was referred to the regional CDC-K laboratory situated on the same compound with USAMRU-K or sent to the South Africa National Institute for Communicable Diseases (NICD). Because of the units' robust safety training, after implementation of the safety program, all employees understood all biosafety levels and could confidently assign an agent into a biosafety level based on the agent's risk assessment. Before 2009, none of the employees understood this. This was one of the indicators for safety program success.

Biosecurity Practices

Biosecurity was inconsistent in USAMRU-K although both physical and electronic security systems were used. Physical security consisted of a 24-hour security guard, a fence around the compound, and padlocks on buildings and laboratory doors. Electronic security consisted of CCTVs in some laboratories, and a keypad system with unique, individually secured five-digit codes assigned to laboratory employees in four out of eight laboratories. The keypad system records employee access to the lab with access denied if an incorrect code is entered. The laboratory manager and safety officer check the codes twice a week to establish if any anomaly had occurred. If an anomaly such as use of a wrong code was found, it was corrected by information technology (IT) personnel, the affected employee advised accordingly, and an incident report written and filed in the employee's, laboratory manager's, and safety officer's files. If this occurred when employees forgot their codes, their code was removed from the system and a new one generated by the IT department.

Data Security and Sample Movement

Data were backed up on the server, with different levels of authority for data access. Some employees could not access data at all, others were given only partial authority, and some were given full authority to both read and write entries. The freezers had freezer locks and key logs, with inventory performed monthly on 10% of the freezer contents. The drawers that store worksheets and record books had key logs that were controlled by the data manager. Different levels of approval were required before a sample was sent out of USAMRU-K. The approval process included the program's principal investigator, the unit safety officer, the institute's ethical review committee, and the Ministry of Health. Import permits from the country to which the sample was being sent were secured prior to sample movement.

Personnel security was lacking in the whole unit. Background checks, essential to more fully understanding the potential employee, were not done during the employment process. This has not been corrected, but discussions are ongoing. After employment, employees were taken through professionalism training where they were introduced to the type of work done at USAMRU-K, data security, chain of communication, and confidentiality. This was very important for research handling highly pathogenic

microorganism (Salerno & Gaudioso, 2007).

The other weakness observed was the lack of restrictions to laboratory access. Any employee could access any laboratory during working hours. Employees working in influenza and viral hemorrhagic fever laboratories could access the sexually transmitted disease laboratory without any restriction during the workday (Table 1). Acceptable practice is that laboratories should be accessed only through authorization.

Perceptions of Risk

Common employee concerns in most of the laboratories included accidental exposure to the agents they were working with without their knowledge and contaminating the environment outside the laboratory (Table 2).

Risks included response to public health outbreaks that may involve emerging pathogens that may become more virulent, more resistant, or more difficult to detect. A public health outbreak could involve some new agents with

Table 1

Biosafety/Biosecurity Practices Employed at USAMRU-K

	AFI	MDR/MDC	HIV	FLU	VHF	ENT	STI
Monitor with CCTV	1	1	1	0	0	0	1
Monitor with 2-way communicator	0	0	0	0	0	0	0
BSC I	0	0	0	0	0	0	0
BSC II	1	1	1	1	1	1	1
Gowns	1	1	1	1	1	1	1
Face shield/goggles	1	1	1	1	1	1	1
Lab autoclave	1	1	1	1	1	1	1
Autoclave QC with tape	1	1	1	1	1	1	1
Autoclave QC with biological indicator	0	0	0	1	1	1	1
Autoclave QC with chemical indicator	0	1	0	0	0	1	1
Autoclave QC with biological and tape	1	0	0	1	1	1	1
Data security	1	1	1	1	1	1	1
Proficiency testing	0	0	0	0	0	0	1
Competency testing	1	1	1	1	1	1	1
BSC servicing	1	1	1	1	1	1	1
Waste decontamination	1	1	1	1	1	1	1
24 hours guard	1	1	1	1	1	1	1
Employee ID	1	1	1	1	1	1	1
Use of keypad	0	0	0	1	0	1	0
Key logs	1	1	0	1	1	1	1
Sample requisition before access	1	0	0	1	1	1	1
Server data back-up	1	1	1	1	1	1	1
Flash disk back-up	0	0	0	0	1	0	0
Restricted levels of laboratory access	0	0	0	0	0	0	0

Key: AFI: Acute febrile illness program; MDR: Malaria drug resistance program; MDC: Malaria Diagnosis Center; HIV: Human immunodeficiency program; FLU: Influenza program; VHF: Viral hemorrhagic fever program; ENT: Enterics program; STI: Sexually transmitted infections program
1: represent 100%; 0.5: represent 50%; 0: represent 0%

Table 2
Occupational Health Practices Employed at USAMRU-K

	AFI	MDR/MDC	HIV	FLU	VHF	ENT	STI
HBV vaccination	1	0.5	1	1	0.5	0.5	0.5
Yellow fever vaccination	1	0.5	0.5	1	1	0.5	0.5
Typhoid vaccination	0	0	0	0	0	0	0
BCG vaccination	1	1	1	1	1	1	1
Rabies vaccination	0	0	0	0	1	0	0
Rift valley fever vaccination	0	0	0	0	0	0	0
Risk assessment for each protocol	1	1	1	1	1	1	1
Risk assessment training	1	1	1	1	1	1	1
Testing after vaccination	0	0	1	0	0	0	0
Exposure from work	0	0	0	0	0	0	0

Key: AFI: Acute febrile illness program; MDR: Malaria drug resistance program; MDC: Malaria Diagnosis Center; HIV: Human immunodeficiency program; FLU: Influenza program; VHF: Viral hemorrhagic fever program; ENT: Enterics program; STI: Sexually transmitted infections program
1: represent 100%; 0.5: represent 50%; 0: represent 0%

different modes of transmission and severity. Other risks include a lack of standard PPE for handling high-risk agents, especially Rift Valley fever and Ebola. Employees saw the risk of sample theft or diversion either by an employee or outsider to be unfounded because they are trained on biosecurity and professionalism before assuming their duties. The risk perception varied from one program to another due to the diversity of the agents.

Discussion

This evaluation sought to gather insight into the status of USAMRU-K's laboratory biosafety and biosecurity practices. This evaluation engaged 98/203 scientists who actively study infectious agents and/or toxins and cleaners (23/23) who take care of the laboratory environment. The specific objectives of the evaluation included identifying the types of pathogens used in the research at different laboratories, policies and procedures designed around biosafety and biosecurity, perceptions of risk for employees, and standards in place. The containment level of an individual laboratory was not sought since all laboratories at USAMRU-K were either BSL-2 or enhanced BSL-2. (enhanced BSL-2 was defined as BSL-2 containment with additional practices not carried out in an ordinary BSL-2.) The results identified three major themes: 1) Although employees were trained on biorisk, biosafety was understood and practiced more than biosecurity; 2) Universal precautions were strictly observed; and 3) Perceptions of risk varied by program as they dealt with different pathogens (influenza virus, pathogens that cause acute febrile illness, those that cause viral haemorrhagic fever, diarrhea pathogens, Lassa virus, and those that cause sexually transmitted diseases). The findings showed that biosafety was implemented at varying levels in every laboratory in USAMRU-K. The primary reason employees used biosafety practices was to reduce the risk of accidentally infecting themselves while working with infectious pathogens. This concern was likely the principal reason why PPE in the form of lab coats, face shields, coveralls, gloves, and safety goggles were used universally. Both personal safety and environmental safety appeared important to the employees, as most of them routinely decontaminated their waste before disposal by autoclaving before incineration. Fifty percent of the laboratories used a biological indicator at least once a month during autoclaving to verify decontamination. Those that did not use a biological indicator gave reasons related to budget constraints. Evidence also suggested that for many, a known risk that cannot be mitigated would result in work not being conducted. Seventy percent of employees claimed that if they did not have a proper piece of laboratory safety equipment necessary to perform an experiment, they did not perform that experiment. What they deemed necessary was based on their training knowledge in biorisk and prior laboratory experience. In addition, employees used a variety of ways to manage their biosafety and biosecurity programs based on the unit's safety program. The most commonly used methods were a biosafety operations manual, biorisk standard operating procedures, a risk assessment and mitigation program that was laboratory-specific, emergency preparedness and response, a biosafety committee, annual and scheduled biosafety trainings, and a

laboratory management plan. Biosecurity issues also appeared frequently in most of the employees' risk assessments. Every program had a working risk assessment and mitigation plan, and each employee was trained and could manage any incident in the laboratory. Nevertheless, other biosafety practices, which are necessary for specific types of research, were used less regularly. For example, dangerous biological agents with the potential to be inhaled during experimental procedures require additional biosafety practices and measures, such as a BSC, one of the most important pieces of laboratory equipment to reduce the risk of inhalational exposure. All laboratories had Class II A2 BSC. All BSC and laboratory equipment maintenance was scheduled twice a year; afterwards, an officer of the Army headquarters (Walter Reed Army Institute of Research, or WRAIR) certified the BSCs and laboratory equipment based on NSF 49 standard and posted a certificate on the specific hoods. In addition, the hoods and other equipment displayed daily maintenance records performed by employees based on specific equipments' standard operating procedures. Daily, at a minimum, employees checked airflow in the hood using a smoke machine or paper towel, read the magnehelic gauge, and tested the exhausted air at the top of the hood. Any out-of-range figures were addressed with a corrective action, logged, and filed in a corrective action folder. In addition, all laboratories that worked with the most dangerous pathogens commonly used controlled access measures (double-door entry, physical isolation of the laboratory); moreover, these laboratories were equipped to handle accidents, as the majority of them had a sealable room for decontamination or an anteroom. In addition, all laboratories had emergency response programs in place. Enhanced biosafety measures, such as an anteroom with a shower and closed-circuit television, were available in (4/8) 50% of the programs at USAMRU-K. Although four of the eight laboratories lacked CCTVs, one had a keypad with unique codes for entry.

No laboratory was allowed to handle an agent that was above its containment level. Such agents were referred to CDC-Kenya or the South Africa NICD, which has BSL-3 containment capacity. Specimens suspected to have Rift Valley fever virus were inactivated on arrival before being sent to CDC-Kenya or NICD-South Africa. This process is spelled out in the USAMRU-K standard operating procedures manual and every employee was trained and signed indicating that they would comply. All employees understood very well the process of risk assessment and can assign any agent to its level of risk if encountered. If they suspect a risk group-4 agent, employees refer it to the National Institute of Communicable Diseases in Johannesburg, South Africa that has a level-4 facility. Currently, South Africa's NICD is the main reference BSL-4 facility on the African continent.

It was also observed that fewer laboratories utilize biosecurity-related measures than biosafety-related measures. The majority of employees (97%) consider theft of samples with the intent to do harm by an employee or nonemployee unfounded. This is due to the biorisk training programs they have completed and professionalism training before employment. The other reason could be the stringent biosecurity regulations (both physical and electronic) put in place by USAMRU-K. Although employees value and observe biosecurity, there is still room for improvement. For example, one laboratory had good sample access and movement tracking, including signing the sample access log, the laboratory manager completing the approval form, and completing another form when the sample was returned to the freezer that also included the time. However, it was observed during the evaluation that on one day employees forgot to fill in the access form when samples were accessed. A further check of the sample access and movement documents showed that they completed a corrective action log indicating why it was not done.

As previously mentioned, the most common biosafety practice was the use of PPE such as gloves, goggles, face masks, coveralls, and gowns. Expensive technologies like two-way communication and pass-through autoclaves are rarely used, most likely because the laboratory containment level at which employees work is BSL-2. Furthermore, most of the sophisticated techniques and equipment were located only in a handful of the laboratories, such as those dealing with influenza and acute febrile illness. When asked about the types of laboratory techniques used with infectious agents and/or toxins, the majority of respondents reported routinely using simple procedures, for example classical polymerase chain reaction (PCR), enzyme-linked immunosorbent assays (ELISAs), sequencing, pulsed field gel electrophoresis, and general electrophoresis (PFGE). Advanced genotyping and gene expression analysis technologies, such as single nucleotide polymorphism (SNP) and RNA interference (RNAi), are not used in the programs.

Biosecurity shows a similar trend. Laboratories located in developing countries tend to choose more personnel-intensive security approaches, relying on guards as their main source of protection. All laboratories in the unit simply post a guard at the building entrance and lock their cabinets, building, and laboratory doors; the use of engineered security controls such as video monitors was employed in half of the programs in the unit. Data were secured on a server with levels of access with different authorities. Sample inventory was done monthly with 10% of freezer inventory done on a monthly basis and 100% of inventory carried out biannually. Personnel-based security measures were inherently less effective; electronic systems were more reliable and had the advantage of providing constant monitoring.

Challenges and Lessons Learned

The introduction of the safety program was difficult since it was a new practice in USAMRU-K. One of the main challenges was resistance to change from the old to the new practices of observing biosafety and biosecurity measures. Since people were used to carrying out duties in a certain way, employees required time to accept being

checked every morning as they reported to work as a security measure at the gate. Following standard operating procedures was difficult for employees. The comment was always, "We have done it this way and nothing happened, and we're still alive and carrying on with duty." The idea of minimum storage of supplies in the laboratory was very difficult to change since the laboratory managers needed to see their laboratory supplies. The corridors were congested and some of the cabinets were kept in the corridors obstructing exit and escape routes. Emergency exits were generally not available and those laboratories with existing emergency exits obstructed them and turned them into sitting spaces. Budget was the other issue. After intensive training, safety gear needed to be provided. This was a challenge because the funds available were mainly geared towards research.

Conclusions

This work has highlighted the strengths and weaknesses of laboratory biosafety and biosecurity in USAMRU-K. The evaluation of the results revealed that participants were actively engaged in research with a wide range of biological agents, including Marburg virus, Chikungunya virus, O'nyong-nyong virus, Dengue virus, Crimean Congo virus, West Nile virus, Influenza virus, *Leptospira*, *Rickettsia*, *Legionella*, *Borrelia*, *Mycoplasma*, *Salmonella* serotype *typhi, Shiga toxigenic Escherichia coli, Shigella dysenteriae*, HIV, and *Neisseria gonorrheae*. The viral hemorrhagic and acute febrile agents are always inactivated on arrival before processing or being referred to a high-containment lab in CDC-Kenya or NICD-South Africa as indicated previously. The other laboratories are BSL-2. In contrast, biosafety and biosecurity practices were varied. Though there were stringent measures to observe biosecurity, biosafety was more prevalent, simple practices and techniques predominate, and perceptions of risk varied per program. One reason why biosecurity was employed less often was because laboratory biosecurity was a relatively new concept, and this was common even in the European, Australian, and U.S. laboratories. Background checks during employment were not conducted. CCTV was not enhanced in all programs.

Recommendations

We highly recommend that new employees go through mandatory background checks that include their character at their former employment and criminal records. Biorisk management training with bloodborne pathogens and infection control, fire safety and evacuation plans, chemical hygiene, general laboratory safety, and occupational health and risk assessment and mitigation should be mandatory. Competence and proficiency testing as stipulated by USAMRU-K should occur.

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