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A Survey of Asian Life Scientists: The State of Biosciences, Laboratory Biosecurity, and Biosafety in Asia

Jennifer G. Gaudioso

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Jennifer Gaudioso
Biological Weapons Nonproliferation Department
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS1371

And

BioInformatics, LLC
2111 Wilson Boulevard
Suite 250
Arlington, VA 22201

Abstract

Over 300 Asian life scientists were surveyed to provide insight into work with infectious agents. This report provides the reader with a more complete understanding of the current practices employed to study infectious agents by laboratories located in Asian countries—segmented by level of biotechnology sophistication. The respondents have a variety of research objectives and study over 60 different pathogens and toxins. Many of the respondents indicated that their work was hampered by lack of adequate resources and the difficulty of accessing critical resources. The survey results also demonstrate that there appears to be better awareness of laboratory biosafety issues compared to laboratory biosecurity. Perhaps not surprisingly, many of these researchers work with pathogens and toxins under less stringent laboratory biosafety and biosecurity conditions than would be typical for laboratories in the West.

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1. EXECUTIVE SUMMARY

The purpose of this study was to examine the policies and standards Asian scientists employ to advance biosafety and biosecurity in their laboratories. Specifically, a need exists to better understand the practices, equipment and facilities used by these researchers and to examine existing regulations in the context of the infectious pathogens they study. By analyzing this information, this survey can help identify and address gaps in the development and implementation of policies related to laboratory biosafety and biosecurity.

The study involved surveying 300 Asian life scientists engaged in research with over 60 different infectious agents and/or toxins. These individuals were divided into three groups based upon the state of their country's research infrastructure:

Advanced
China
Hong Kong
Japan
Korea
Singapore
India

Emerging
Pakistan
Thailand
Taiwan
Malaysia

Developing
Indonesia
Cambodia
Vietnam
Bangladesh
Philippines
Sri Lanka

Most of the laboratories profiled in the study perform risk assessments as the antecedent to instituting a biosafety plan. These plans, along with a laboratory's biosecurity practices are highly influenced by each country's national government. However, what constitutes an assessment, much less biosafety and biosecurity plans, varied by country tier as well as by class of organism studied. Part of this variability came from the respondents' characterization of their agent's potential for harm. Five of the top nine infectious agents identified by respondents should be studied under biosafety level (BSL) 3 conditions, however almost two-thirds of researchers—in some cases—state they are working only with BSL 2 practices.

Following on this perception of harm theme, the study was also designed to investigate the definitions of risk as it pertains to the term “containment.” Respondents were questioned regarding the procedures they use to minimize or eliminate the exposure of researchers, people outside the laboratory, and the external environment to the infectious material they study. Respondents were far more concerned about accidental exposure and its consequences than intentional breaches of security. Study respondents face unique challenges in not only securing and safeguarding their samples, but also in just performing their research. Because practice and protection are interlinked, the study also examined the role and relevance of technologies utilized by Asian scientists. When performing these various investigations, respondents most often use classical PCR, electrophoresis and enzyme-linked immunosorbent assays (ELISAs). More sophisticated technologies—typically used for gene expression analysis—like microarrays and RNAi are not as popular. Cost and access to resources were two key obstacles respondents regularly face.

This study spotlights the intersection of the risks Asian scientists feel in researching specific pathogens and links these perceptions with the realities of their biosafety and biosecurity policies and procedures. It provides the reader with a more complete understanding of the current practices employed in studying infectious agents and pathogens by laboratories located in Asian countries—segmented by level of biotechnology sophistication.

2. STUDY OBJECTIVES AND SIGNIFICANT FINDINGS

2.1 Study objectives

From the perspective of researchers working with potentially hazardous biological agents, the primary objectives of this assignment will be exploratory in nature and designed to assess:

- Types of pathogens and/or toxins used in research
- Research objectives as they pertain to these pathogens and/or toxins
- Laboratory capacity including tools and techniques available, personnel, physical structure
- Status quo for biosafety and biosecurity policies and procedures
- Perceptions of risk
- Standards and accountability measures

2.2 Significant findings

- Three bacterial strains dominate research focus: *Salmonella typhi*, *Escherichia coli* O157:H7, *Vibrio cholerae*
- Diagnostics and epidemiology influence research tools and priorities
- Most laboratories perform detailed risk assessments
- Countries' governments shape biosafety and biosecurity practices
- BSL 2 practices often employed for BSL 3 agents
- Simple biosecurity measures routinely utilized
- Researchers do not tend to worry about the potential for a security breach
- Majority of laboratories share samples
- Cost and access to resources hamper researchers

3. THREE BACTERIAL STRAINS DOMINATE RESEARCH FOCUS

A variety of infectious agents and toxins are studied.

Unsurprisingly respondents representing such diverse fields as virology, microbiology, toxicology, and pathology perform research on a wide variety of organisms. Despite this assortment, some distinct trends emerge. More respondents have a preference for studying diseases caused by bacteria. *Salmonella typhi* and *Escherichia coli* O157:H7 are the most commonly studied bacteria. In addition to these two organisms, *Vibrio cholerae*, was the third most frequently investigated infectious agent.

Slightly more than one-third of respondents do work on infectious agents that were not specifically listed in the survey. The most popular of these agents cause diseases endemic to Asia and developing countries: tuberculosis, hepatitis, and malaria. Toxins were the least studied biohazards. More respondents investigate *Staphylococcus aureus* toxins than any other toxin.

Human Immunodeficiency Virus (HIV) and dengue fever virus are the most universally studied viruses. In contrast to their counterparts in the *Advanced* and *Emerging* countries, respondents from the Developing countries also place a special emphasis on dengue fever virus as well as severe acute respiratory syndrome (SARS) and avian influenza. Given the tremendous economic and social impact of dengue fever, many Asian countries are investing in measures to combat a potential epidemic. Indonesia has been most severely affected—suffering over one-third of all infections and two-thirds of all deaths from the disease.[1]

[1] http://www.iht.com/articles/2005/09/28/news/fever.php

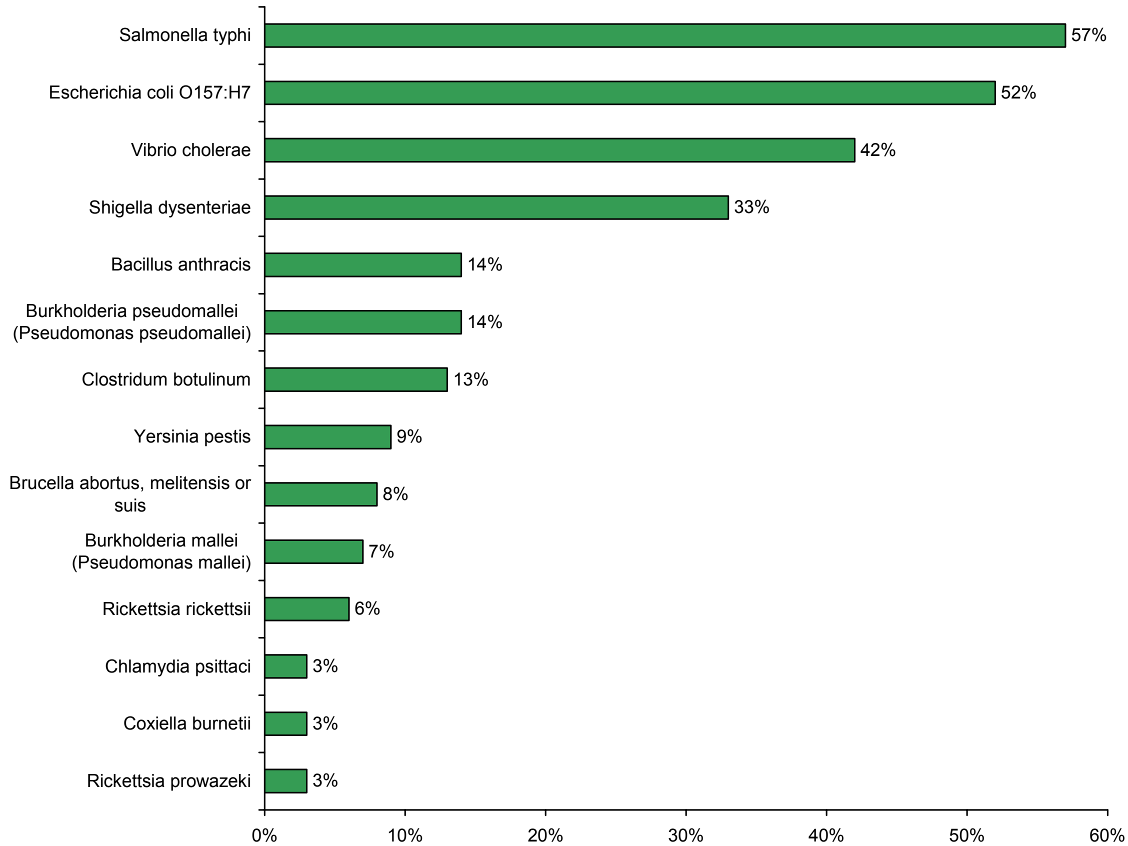

Figure 1. Types of Bacteria Studied by Respondents

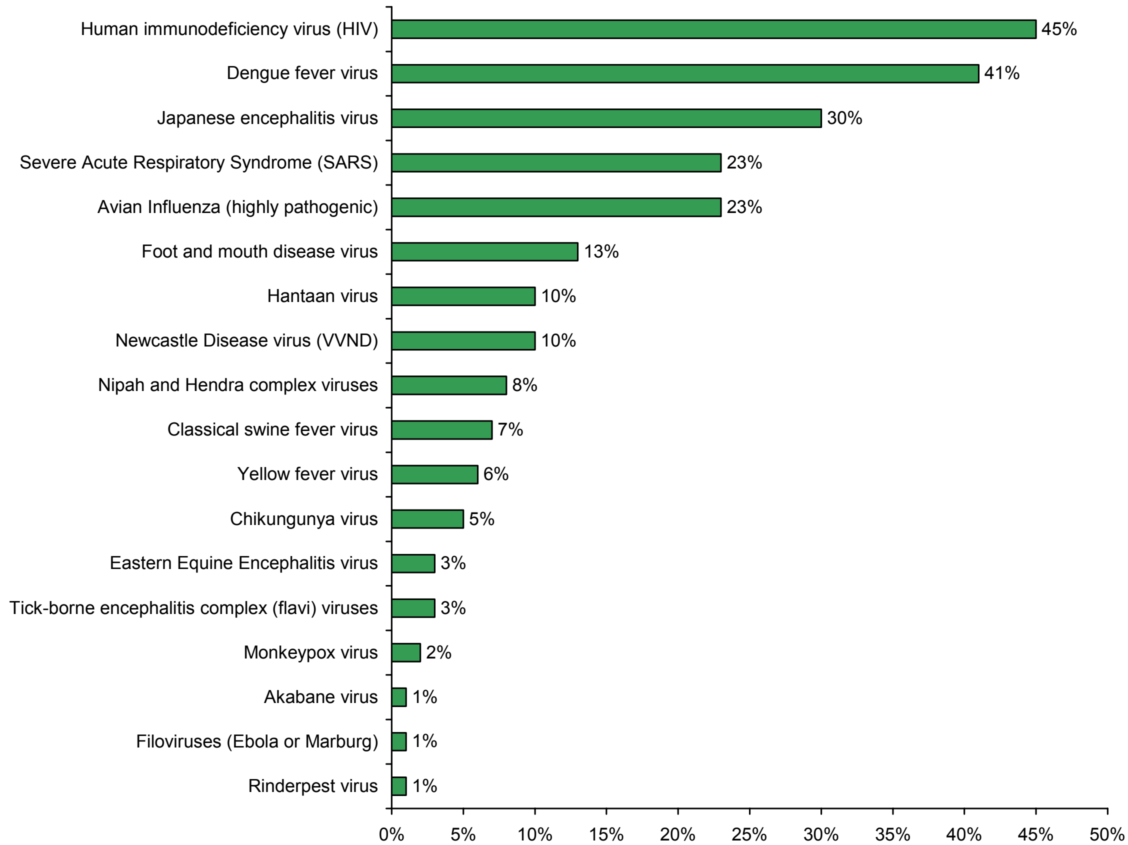

Figure 2. Types of Viruses Studied By Respondents

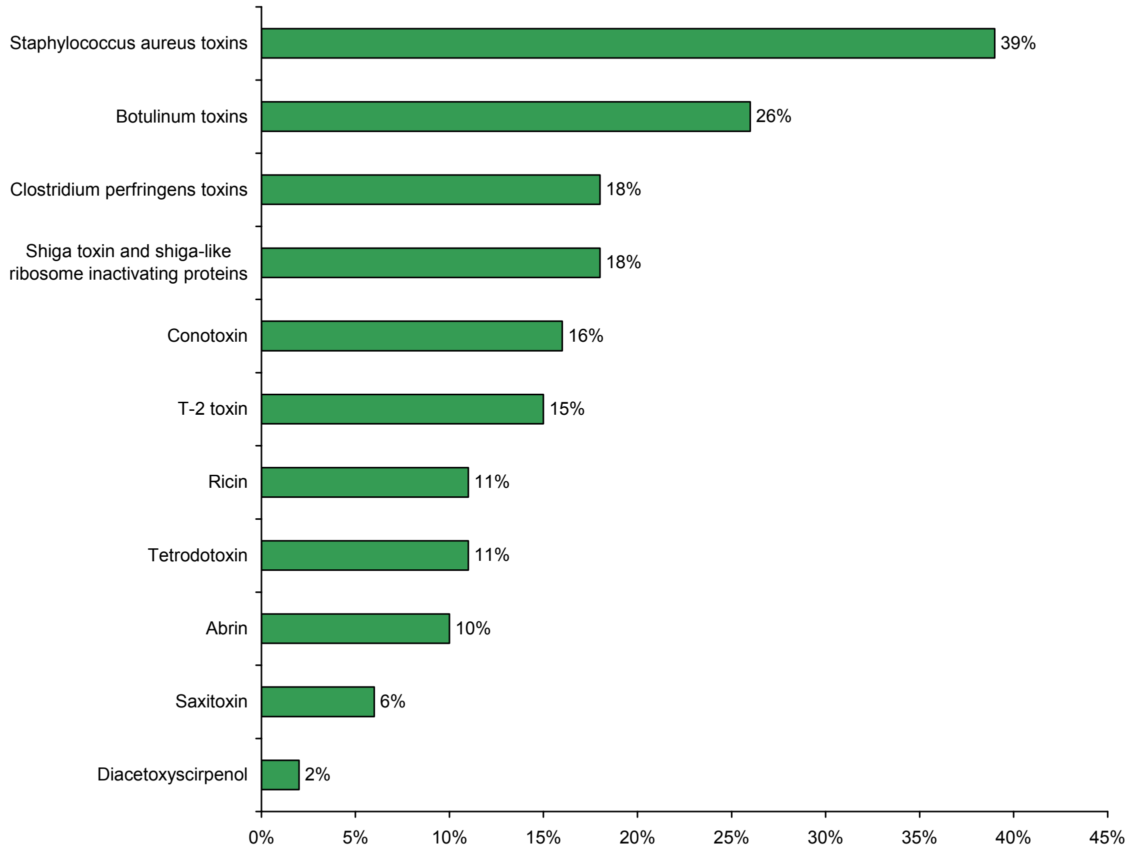

Figure 3. Types of Toxins Studied by Respondents

Infectious Agents Studied by Country Tier	Advanced	Emerging	Developing	Total Respondents
Salmonella typhi	31%	22%	21%	27%
Escherichia coli O157:H7	28%	22%	19%	25%
Vibrio cholerae	19%	22%	21%	20%
Human immunodeficiency virus (HIV)	20%	13%	17%	17%
Dengue fever virus	10%	15%	34%	16%
Shigella dysenteriae	17%	13%	17%	16%
Japanese encephalitis virus	9%	12%	21%	12%
Severe Acute Respiratory Syndrome (SARS)	9%	9%	11%	9%
Avian Influenza (highly pathogenic)	4%	9%	23%	9%
Staphylococcus aureus toxins	10%	7%	4%	8%

Figure 4. Top Infectious Agents Studied by Country Tier

4. RESEARCH CAPABILITIES

Diagnostic needs and epidemiology influence research tools and priorities.

Slightly more than one-third of respondents conduct basic research. The majority of the remaining researchers are evenly divided into the following areas: drug discovery and development, clinical work, and disease surveillance.

Respondents identified diagnostics and epidemiology as the major focus of their research efforts. However, depending upon what stage of research respondents are involved in, there was a different focus. For instance, basic researchers were more often associated with pathogenesis studies while clinicians focused more on diagnostics. Given that many respondents investigate bacterial-caused infections, it would be expected that more drug discovery and development researchers work on antibiotics rather than on antivirals.

More respondents from *Advanced* countries work in the area of diagnostics than epidemiology. For those respondents from *Emerging* countries this split between the two disciplines is about equal. However, for respondents from *Developing* countries, the emphasis shifts from diagnostics to epidemiology.

As epidemiology is most closely linked to disease surveillance, many of the respondents' laboratories in the *Developing* countries likely serve a critical public health need. In fact, they are about 1.5 times *more* likely to be repurposed by their governments to assist during an epidemic than their counterparts in *Emerging* and *Advanced* countries.

When performing these various investigations, respondents most often use classical PCR, electrophoresis and enzyme-linked immunosorbent assays (ELISAs). More sophisticated technologies—typically used for gene expression analysis—like microarrays and RNAi are not as popular.

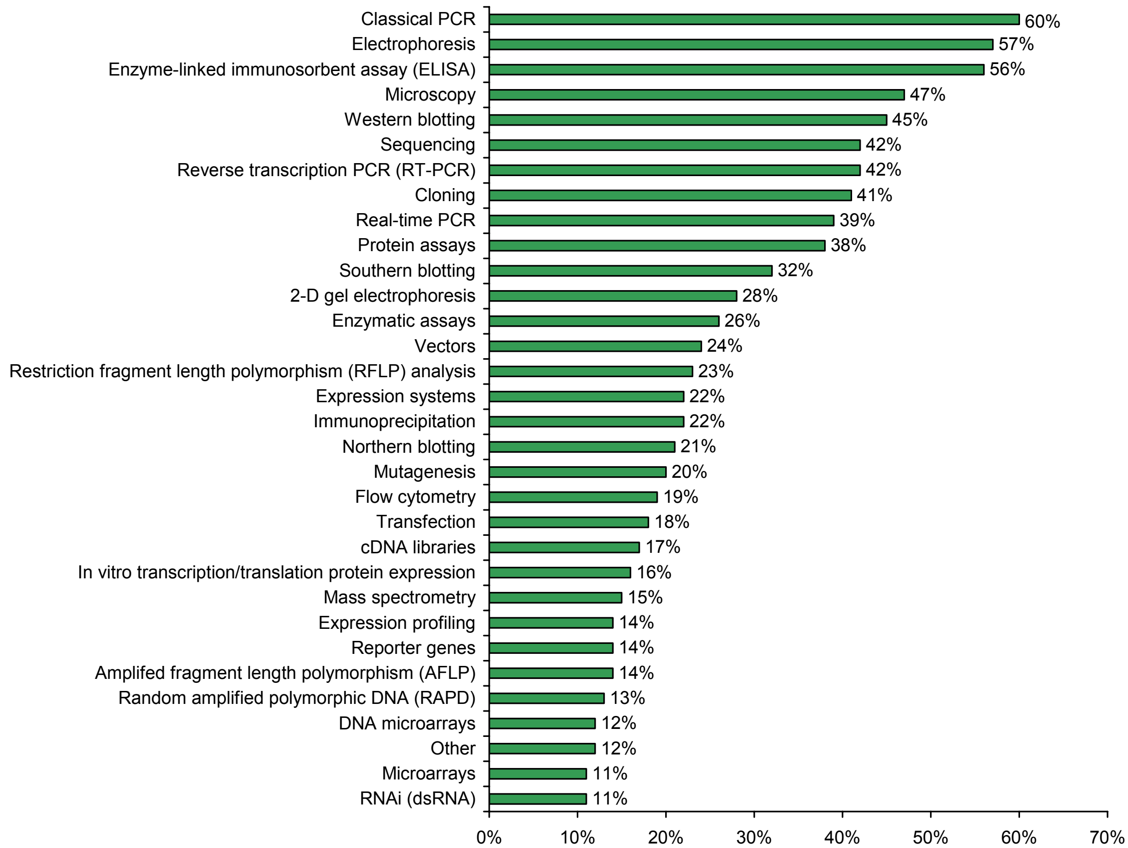

Figure 5. Research Techniques used by Respondents

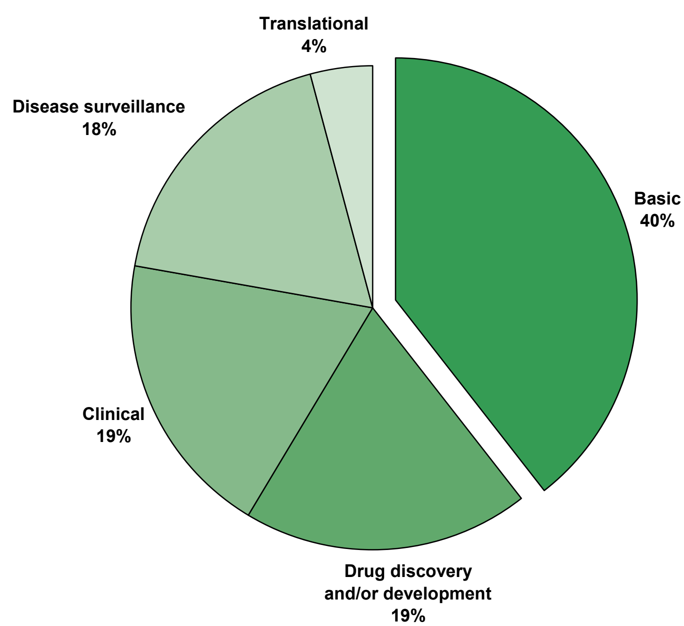

Figure 6. Major Research Focus of Respondents

5. STANDARD OPERATING PROCEDURES FOR RISK ASSESSMENT

Most laboratories perform detailed risk assessments.

A risk assessment is a scientifically based process that sets up the framework for constructing comprehensive biosafety and biosecurity architecture. It typically comprises four phases: hazard identification, hazard characterization, exposure assessment and risk characterization. The vast majority of study respondents' laboratories perform a risk assessment.

Many respondents take into account what types of laboratory procedures they plan to undertake when performing this assessment. Approximately half of the respondents indicated that their laboratories also consider the natural route of infection or the agent's pathogenicity during a risk assessment. Additional factors likely to be factored into a risk assessment include:

- Concentration and volume;
- Alternative routes of infection;
- Exposure outcome;
- Availability of prophylaxis;
- Agent or toxin stability.

Biosecurity issues do not figure as predominantly in most of the respondent's risk assessments. For example, one-fifth of respondents' laboratories assess the potential for malicious use of the infectious agent or toxin they study. Moreover, a solid majority of respondents believe that it is very unlikely that either a disgruntled employee or bioterrorist unassociated with their laboratory would ever steal samples with the intent of causing harm.

Only 14% of laboratories do not regularly perform risk assessments. Proportionally more of these laboratories are located in *Advanced* and *Emerging* countries rather than in *Developing* countries.

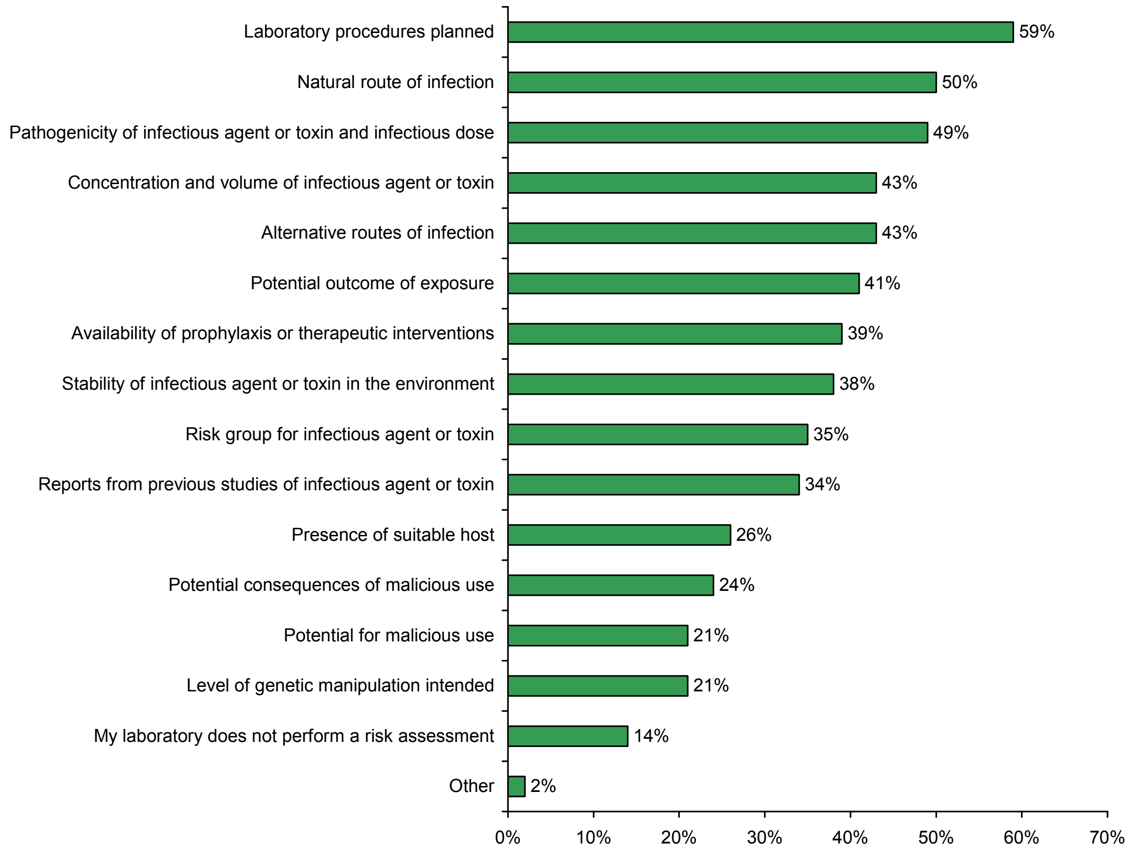

Figure 7. Factors Respondents Consider for Risk Assessments

6. BIOSAFETY AND BIOSECURITY REGULATIONS AND MANAGEMENT

Countries' governments largely shape laboratory biosafety and biosecurity practices.

The majority of respondents receive biosafety and biosecurity regulations from their countries' governments. Approximately half of all respondents use the World Health Organization (WHO)'s Laboratory Biosafety Manual. Respondents whose laboratories reside in *Advanced* and *Emerging* countries rely more on the regulations provided by their respective governments than respondents from *Developing* countries. Slightly more of these respondents depend upon the WHO regulations than their own government's regulations.

As the Biosafety Level (BSL) increases from 1 to 2 and from 2 to 3, it appears as if more respondents' laboratories turn to additional sources of regulations outside their own country. The two principal resources are WHO's "Laboratory Biosafety Manual" and the Center for Disease Control and Prevention's (CDC) "Biosafety in Microbiology and Biomedical Laboratories."

Thus, WHO's authority on laboratory safety and security is likely better recognized or more needed by countries who may not have the infrastructure or experience to have their own guidelines. Additionally, laboratories that work on infectious agents that are increasingly hazardous seek WHO's or the CDC's recommendations on more stringent laboratory practices, safety requirements and facilities than BSL 1 laboratories.

Respondents' organizations use a variety of different means to manage their biosafety and biosecurity programs. The most common ones are a biosafety operations manual, an institutional biosafety committee, biosafety training procedures, and a laboratory management plan. There is a stronger emphasis on using a biosafety operations manual as the BSL increases from 1 to 2 and from 2 to 3.

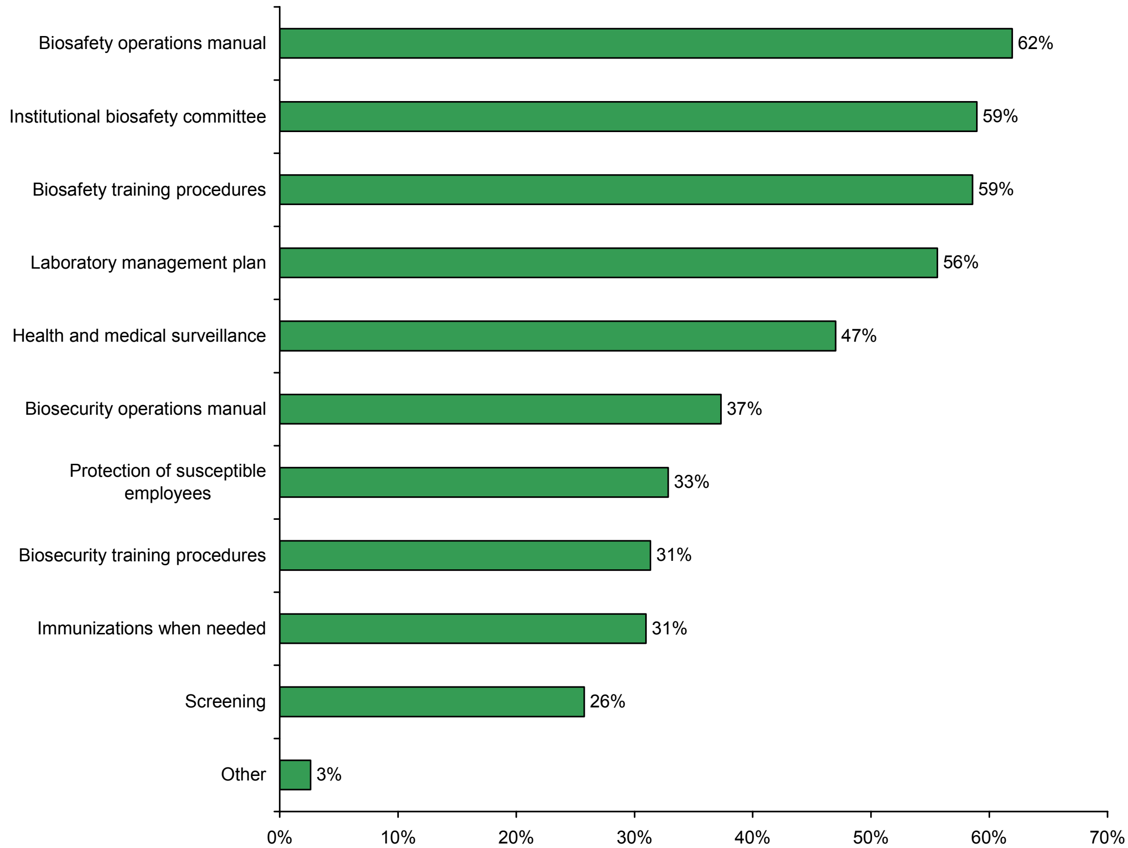

Figure 8. How Biosafety and Biosecurity Programs are Managed

	Advanced	Emerging	Developing
My country's government	71%	57%	57%
World Health Organization (WHO)	44%	45%	61%
Center for Disease Control (CDC)	28%	43%	35%
Laboratory director(s)	22%	31%	22%
Our lab does not employ any specific laboratory policies	6%	8%	9%
Asia BioNet	9%	5%	4%
International Biosafety Working Group (IBWG)	7%	6%	9%
Food and Agriculture Organization of the United Nations	5%	7%	9%
Laboratory Centre for Disease Control (LCDC), Canada	4%	10%	2%
Other	4%	5%	4%
Office International des Epizooties (OIE)	4%	6%	0%

Figure 9. Entity Providing Biosafety and Biosecurity Regulations

7. BIOSAFETY PRACTICES

BSL 2 practices are often employed for BSL 3 agents.

Slightly less than half of respondents work at BSL 2. Surprisingly, 21% of respondents do not know what biosafety level they currently work at with their infectious agent or toxin. Five of the top nine infectious agents identified by respondents should be studied under BSL 3 conditions according to WHO and the CDC. However, nearly two-thirds of respondents investigating Japanese encephalitis, avian influenza, and severe acute respiratory syndrome (SARS) perform their research under BSL 2 specifications. Furthermore, 54% studying human immunodeficiency virus and 62% working on *Escherichia col*i 0157:H7 use a BSL 2 environment.

One explanation for this discrepancy is that some of these labs are diagnosing clinical specimens, which then require only BSL 2 work practices. Another possibility is that respondents' laboratories are not able—whether it is from ignorance, lack of resources, or disregard for authority—to work at the appropriate biosafety level.

Alternatively, respondents may claim to be working at one biosafety level, but are actually employing more stringent safety practices. For example, more than half of the labs working with the most dangerous organisms do have some degree of controlled access (i.e., double-door entry and physical isolation of laboratory, etc.) and special ventilation (i.e., HEPA-filtered air exhaust). However, these laboratories do not appear equipped to handle accidents as the majority of them lack a sealable room for decontamination, controlled ventilating system, and an anteroom. Nonetheless, for personal protection, the majority of respondents use personal protection such as gloves, face shields and gowns. Two-thirds of respondents decontaminate their waste before disposal. Slightly more than half of the respondents have an autoclave on site for this purpose.

If respondents do not have a particular piece of safety equipment necessary to perform an experiment, just under half of them will do the experiment anyway by either by modifying existing equipment or creating new pieces of equipment. Respondents from *Emerging* and *Developing* countries are more likely to modify existing equipment than create new pieces of equipment while an equal percentage of respondents from *Advanced* countries do either.

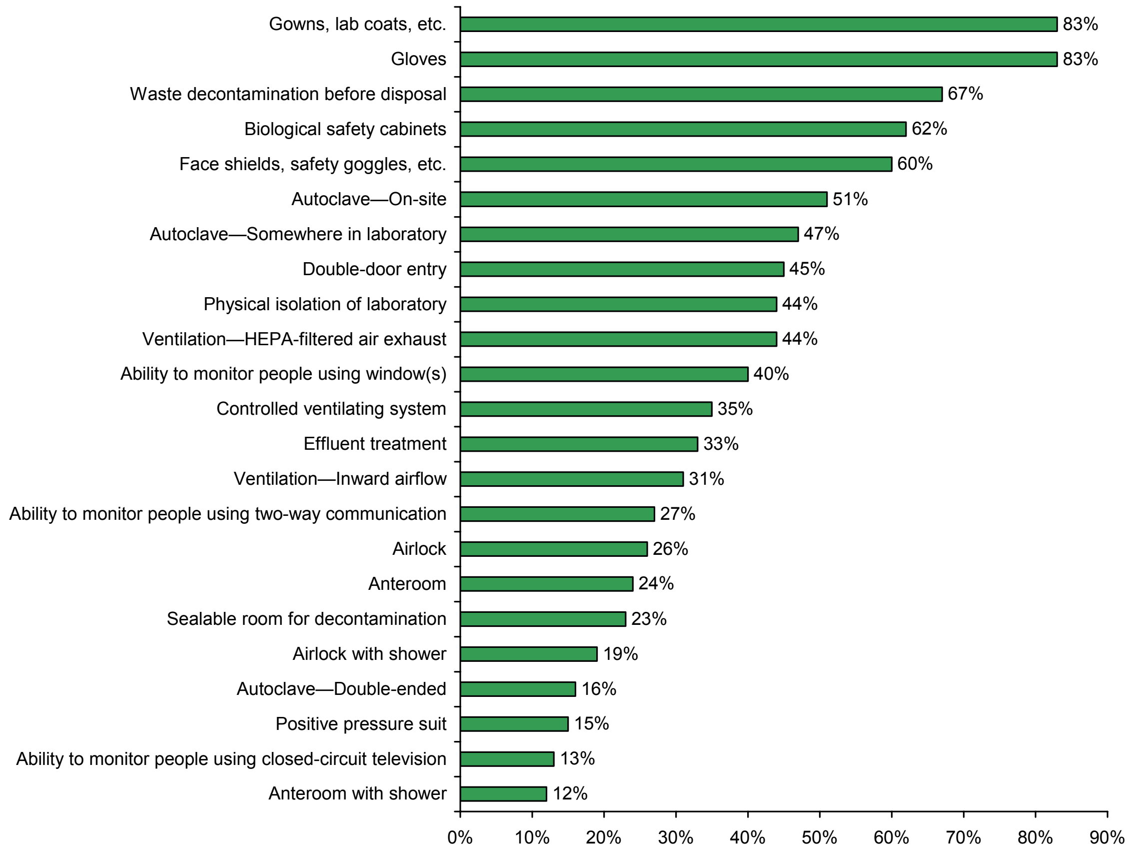

Figure 10. Biosafety Practices Employed by Respondents

	8. At which biosafety level does your laboratory practice when working with these infectious agents and/or toxins? (choose only one)		
	Biosafety Level 1 (BSL1 or P1)	**Biosafety Level 2 (BSL2 or P2)**	**Biosafety Level 3 (BSL3 or P3)**
	Row %	Row %	Row %
Escherichia coli O157:H7	22%	62%	16%
Salmonella typhi	24%	62%	14%
Vibrio cholerae	16%	67%	16%
Human immunodeficiency virus (HIV)	12%	55%	33%
Shigella dysenteriae	21%	61%	18%
Dengue fever virus	8%	69%	22%
Japanese encephalitis virus	6%	67%	27%
Avian Influenza (highly pathogenic)	4%	65%	30%

Figure 11. Biosafety Levels Employed for Research on Top Pathogens

8. BIOSECURITY PRACTICES

Simple biosecurity measures are routinely utilized.

At least half of the respondents' laboratories always have a guard at the buildings entrance, lighted buildings at night, and locked cabinets. Other security measures used around the clock by at least one-third or more of the respondents are access control devices, locked building doors and refrigerators, and security patrols. Laboratories located in *Developing* countries, in contrast to those located in *Advanced* and *Emerging* countries tended to be personnel heavy with their security measures (e.g., guards and patrols). More sophisticated protections such as intrusion sensors and alarms as well as video monitors are not nearly as commonplace physical security measures.

Slightly more than half of the respondents' laboratories restrict access to laboratory areas at all times. At least two-fifths of respondents' laboratories always know who is qualified to be in the restricted areas by having a list of employees with access, photo identification badges and records of keycard assignments. Building escorts are probably the most variable personnel security measure and most often are done in the laboratories of *Advanced* countries. Background screening seemed to occur more frequently in laboratories located in *Developing*, rather than *Advanced* and *Emerging* countries.

Password protection of computers and files is the most likely information security measure to be employed on a constant basis. Maintaining a laboratory's computer network and destroying sensitive documentation are measures slightly more than one-half of respondents' laboratories always perform.

Awareness of infectious agents or toxins by either the laboratory head or direct supervisor is one of the most common ways the majority or respondents' laboratories ensure material control measures. The majority of the laboratories appear to regularly employ a variety of material control measures whether they are shipping infectious agents using International Air Transport Association (IATA) Dangerous Goods Regulations or obtaining appropriate permission to share infectious agents or toxins with other labs.

		All of the time	Most of the time	Some of the time	Little of the time	None of the time	Total Respondents
Physical Security	Guard at building entrance(s)	54%	15%	7%	7%	17%	251
	Locked doors to laboratory room(s)	53%	23%	15%	2%	6%	259
	Lighted building at night	51%	18%	11%	6%	14%	241
	Locked cabinets	50%	24%	10%	4%	13%	255
	Unobstructed views of entrance(s)	45%	16%	11%	6%	22%	252
	Locked doors to building	44%	28%	14%	5%	10%	256
	Self-closing doors	41%	17%	8%	3%	31%	264
	Access control devices	36%	25%	17%	5%	17%	248
	Locked refrigerators	34%	23%	17%	8%	19%	252
	Security patrols	33%	22%	19%	7%	19%	245
	Intrusion sensors and alarms	32%	12%	10%	5%	41%	237
	Video monitors	25%	10%	4%	4%	57%	243

Figure 12. Frequency of Physical Security Measures Employed

		All of the time	Most of the time	Some of the time	Little of the time	None of the time	Total Respondents
Personnel Security	Restricted access to laboratory areas	51%	23%	12%	7%	8%	100%
	List of employees who have access to restricted areas	48%	21%	7%	9%	15%	100%
	Photo identification badges	46%	18%	9%	4%	24%	100%
	Records of keycard/key assignments	45%	14%	12%	6%	23%	100%
	Biosecurity training for new employees	44%	21%	17%	10%	8%	100%
	Background screening for potential employees	34%	24%	16%	10%	16%	100%
	Building escorts for non-employees	28%	22%	18%	9%	23%	100%

Figure 13. Frequency of Personnel Security Measures Employed

		All of the time	Most of the time	Some of the time	Little of the time	None of the time	Total Respondents
Information Security	Computers and/or computer files are password protected	54%	22%	11%	5%	8%	100%
	Computer/network security maintained	51%	20%	9%	4%	15%	100%
	Sensitive documentation is destroyed before putting in trash	51%	21%	12%	4%	12%	100%
	Off-site storage of data and/or information is secure	43%	24%	16%	4%	14%	100%
	Storage of paper, tapes, and videos in secure container(s)	38%	28%	14%	5%	14%	100%

Figure 14. Frequency of Information Security Measures Employed

		All of the time	Most of the time	Some of the time	Little of the time	None of the time	Total Respondents
Material Control	Laboratory head is aware of all infectious agents and/or toxins studied in lab	76%	18%	3%	1%	1%	267
	Direct supervisor is aware of all infectious agents and/or toxins studied in lab	69%	21%	5%	3%	3%	267
	Shipment of infectious agents and/or toxins using International Air Transport Association IATA Dangerous Goods Regulations	64%	16%	8%	3%	9%	255
	Appropriate permission(s) obtained to share infectious agents and/or toxins with other investigators/labs	59%	22%	10%	5%	5%	263
	Organization director is aware of all infectious agents and/or toxins studied in all labs	58%	21%	11%	7%	3%	265
	Infectious agents and/or toxins not in use are destroyed	56%	21%	11%	7%	5%	261
	Current inventory of infectious agents and/or toxins	54%	23%	9%	6%	7%	254

Figure 15. Frequency of Material Control & Accountability Measures Employed

9. RISK PERCEPTIONS

Researchers do not tend to worry about the potential for a security breach.

While not a very high priority when conducting a risk assessment, nearly one-fourth of respondents consider the potential consequences of misuse of the infectious agent or toxin they study. According to the majority of respondents, however, this scenario is likely a remote possibility. They do not believe that either an employee or non-employee would steal their laboratories samples with the intent of causing harm.

Nevertheless, half of the respondents are very worried about the possibility that the infectious agent or toxin they study could accidentally infect others outside the laboratory. Slightly less than 50% are also very apprehensive that they themselves could acquire an infection.

About twice as many respondents from laboratories in *Developing* countries than in *Advanced* and *Emerging* countries believe that they will be involved in discovering an emerging infectious disease. This belief could reflect the public health vulnerabilities of many of these countries:

- Limited or no access to effective drugs;
- Intense economic pressures;
- Population movement;
- Changes in land use;
- Malnutrition.

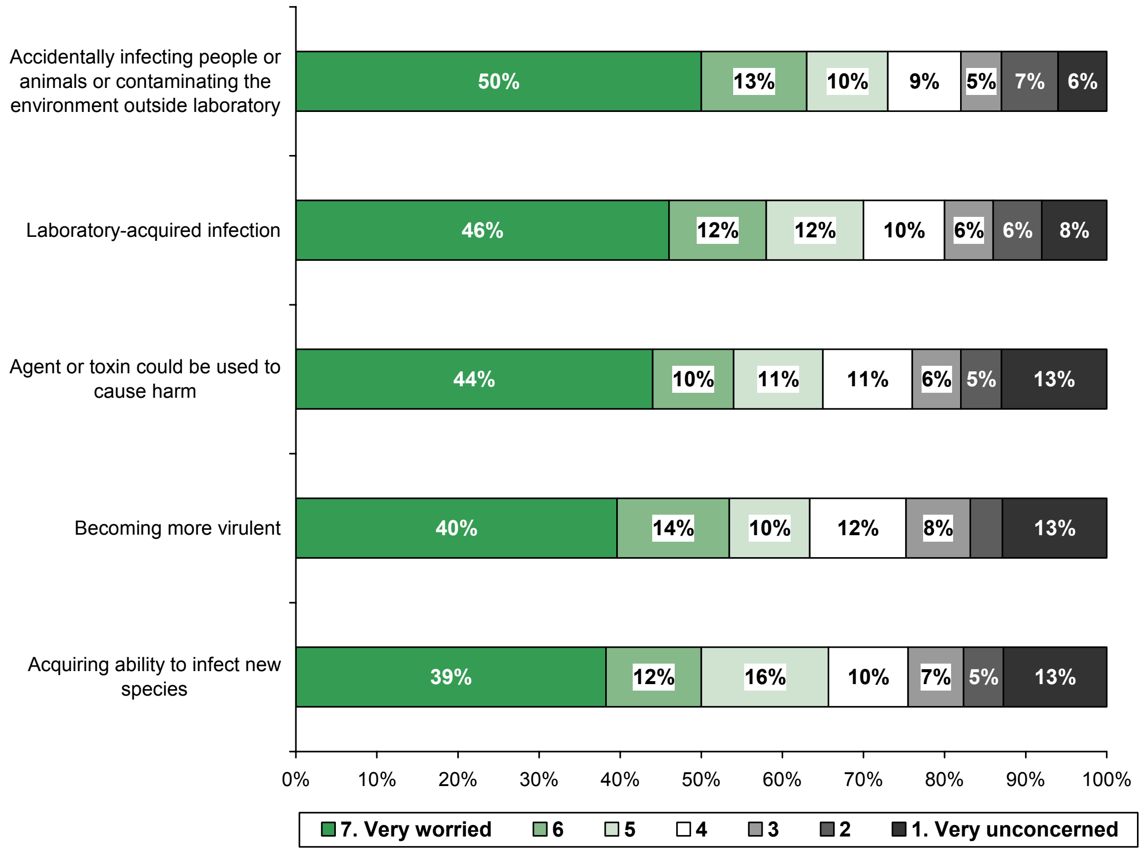

Figure 16. Biosafety and Biosecurity Risk perceptions of Respondents

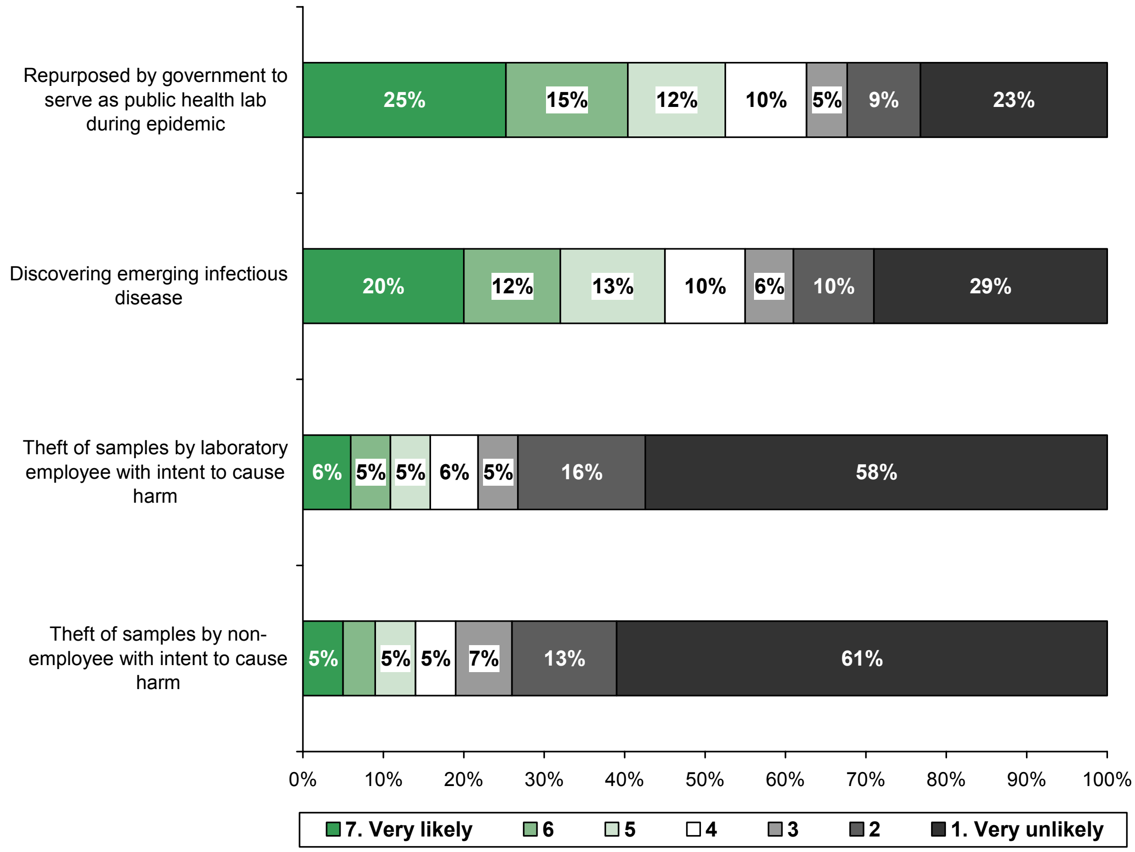

Figure 17. Likelihood that Respondent's Laboratory would be Impacted by Various Scenarios

10. COLLABORATIONS

The majority of laboratories share samples.

Reading journals and attending conferences is how the majority of respondents stay abreast of developments in their field. More respondents in *Developing* countries than either *Advanced* or *Emerging* countries prefer conferences over journals as a means of maintaining scientific literacy.

Many respondents also stay connected with their scientific colleagues via collaborations. Only 8% of respondents' laboratories do not collaborate. Most of these relationships are either established locally (i.e., within one's organization) or within one's country. About 8% more respondents collaborate with researchers in the United States than they do with researchers located elsewhere in Asia. This increased reliance on American scientists is more evident in laboratories located in *Developing* rather than *Advanced* or *Emerging* countries.

In regard to the frequency of sample exchange, 33% of respondents share samples every few months or so. Another 28% of respondents share once a year and approximately one-quarter never share samples. A greater percentage of respondents from *Developing* countries share samples with their collaborators every few months than respondents from *Advanced* and *Emerging* countries. Respondents from these two last sets of countries are equally divided three ways on the frequency of their sharing: every few months, yearly basis or never (p. 3-37 and 3-41). Regardless of whatever arrangements employed, limited access to infectious agents or toxins is *not* a significant problem for the vast majority of respondents.

	Advanced	Emerging	Developing
My organization	60%	62%	59%
My country, not including my organization	55%	71%	59%
United States	32%	26%	57%
Other countries within Asia	23%	25%	39%
United Kingdom	13%	21%	15%
Other	8%	13%	33%
Australia	7%	12%	33%
France	4%	8%	24%
My laboratory does not collaborate.	9%	6%	7%
Germany	7%	6%	11%
Canada	5%	4%	9%

Figure 18. Location of Collaborations by Country Tier

	Advanced	Emerging	Developing
Daily	2%	1%	4%
Weekly	6%	2%	7%
Monthly	8%	1%	11%
Once every few months	29%	33%	44%
Yearly	27%	31%	24%
Never	28%	31%	9%

Figure 19. Frequency of Sample Sharing by Country Tier

11. CHALLENGES

Cost and access to resources hamper researchers.

Almost half of respondents report experiencing a middling level of difficulty—half way between very difficult and very easy—when conducting research on their infectious agent. Expense, lack of equipment, and delayed shipments are top problems researchers experience. However, most difficulties are particularly country tier-specific.

Respondents from *Advanced* countries most often complain about the expense of conducting their research. The cost of research is also a concern for respondents from *Emerging* and *Developing* countries, but typically other problems overshadow it. For example, respondents in *Emerging* countries also cite limited access to necessary equipment, lack of qualified staff, and difficulty in shipping infectious agents as troubles they experience. Respondents from *Developing* countries also worry about the lack of appropriate instrumentation and delayed shipments of lab supplies.

Respondents also face other limitations when conducting their research. Greater than one-third of them require outside assistance with animal models. Respondents whose laboratories are located in either *Advanced* or *Emerging* countries also need support in preparing or obtaining antibodies for capture and differentiation. In contrast, respondents whose laboratories are located in *Developing* countries state that they most often need help with determining virulence-associated traits, distinguishing characteristics and diagnosis, and cultivating the infectious agents that they study.

	Advanced	Emerging	Developing
Animal models	39%	41%	29%
Antibodies for capture and differentiation	28%	36%	33%
Virulence-associated characteristics	24%	30%	43%
Biochemical/taxonomic characterization	24%	24%	31%
Distinguishing characteristics and diagnosis	21%	23%	36%
Infectious dose	22%	17%	31%
Cultivating	15%	23%	36%
Subtyping	16%	19%	31%
Sampling and enrichment techniques	20%	13%	24%
Detecting infected cells	17%	14%	24%
Life cycle(s)	14%	19%	19%
Reservoirs and routes of transmission	12%	20%	24%
Route of contamination	15%	12%	24%
Host range	13%	14%	24%
Our laboratory does not require assistance from outside experts	17%	13%	10%
Geographic range and seasonality	13%	12%	19%
Subpopulations at risk	7%	11%	17%
Sequelae	7%	8%	12%
Other	1%	4%	5%

Figure 20. Research Techniques Respondents Require Outside Assistance from Collaborators by Country Tier

	Advanced	Emerging	Developing
Too expensive	41%	37%	33%
Lack of necessary equipment	30%	39%	49%
Delayed shipments of reagents and/or equipment	34%	32%	47%
Lack of qualified staff	29%	37%	33%
Difficulty in shipping infectious agents and/or toxins for secondary analysis	26%	37%	22%
Excessive documentation	25%	28%	11%
Unavailability of reagents and/or equipment	17%	28%	33%
Inadequate biosafety	15%	23%	31%
My laboratory does not typically have any problems in conducting research on these infectious agents and/or toxins	19%	20%	13%
Limited access to infectious agent(s) and/or toxins	16%	21%	13%
Inadequate biosecurity	11%	18%	22%
Isolated from other scientists working on same infectious agents and/or toxins	13%	16%	16%
Burdensome security measures	16%	12%	7%
Publication restrictions	11%	17%	11%
Lost or stolen shipments of reagents and/or equipment	3%	1%	2%

Figure 21. Problems Respondents Face in Conducting Research by Country Tier

12. CONCLUSIONS

In general, respondents seem more aware of possible biosafety concerns than potential biosecurity threats in regard to the infectious agent and/or toxin studied in their laboratory. A strong majority—86% of respondents—conduct a relatively detailed risk assessment to help them decide which pieces of safety equipment to use and what types of security measures (e.g., physical, personnel, information, or material control) to institute. Even so, many respondents' ignorance or dismissal of the possible harm a particular pathogen might cause, in the event of accidental exposure, is worrying. Half of respondents consider the natural route of infection or the agent's pathogenicity, yet the majority of respondents studying such infectious agents as *Escherichia coli* O157:H7, human immunodeficiency virus (HIV), Japanese encephalitis virus, avian influenza and severe acute respiratory syndrome (SARS) do so at one biosafety level lower than that recommended by the World Health Organization (WHO) and/or the Centers for Disease Control and Prevention (CDC).

While most respondent's laboratories employ simple biosecurity measures, the fact that the awareness level and perceived threats about biological terrorism is not very high suggests that these safeguards might be quite vulnerable. This susceptibility is likely to be even greater for those laboratories that strongly rely on security provided by humans (e.g. entry way guards or security patrols) rather than technology, a trend that is more typical of laboratories located in *Developing* countries than in *Advanced* and *Emerging* countries. Another reason to be concerned about the degree of biosecurity in the *Developing* nations is that in contrast to their counterparts in the other two country tiers, these respondents also place a special emphasis on such restricted agents as dengue fever virus, SARS, and avian influenza. Additionally, about twice as many respondents from laboratories in *Developing* countries than in *Advanced* and *Emerging* countries believe that they will be involved in discovering an emerging infectious disease. The actual and theoretical focus of respondents from *Developing* countries on diseases that have the potential to create devastating pandemics must be a major public health concern. Consequently where biosecurity guidelines exist, there needs to be improved access to information on these methods, and review, adaptation, and refinement of these methods in the Asian context.

Fortunately, the study indicates that these respondents might be receptive to credible, unbiased information on biosafety and biosecurity policies and procedures. One straightforward way to do so is to take advantage of respondents' desire to stay connected with their scientific colleagues via collaborations. Only 8% of respondents' laboratories do not collaborate. Most of these relationships are either established locally (i.e., within one's organization) or within one's country. About 8% more respondents collaborate with researchers in the United States than they do with researchers located elsewhere in Asia. This increased reliance on American scientists is especially evident in laboratories located in *Developing* rather than *Advanced* or *Emerging* countries. Additionally, as the BSL increases from 1 to 2 and from 2 to 3, it appears as if more respondents' laboratories turn to additional sources of regulations outside their own country. The two principal resources are WHO's "Laboratory Biosafety Manual" and the Center for Disease Control and Prevention's (CDC) "Biosafety in Microbiology and Biomedical Laboratories." These collaborations could be channels by which experiences and the results of risk assessment; good practices; and biosafety and biosecurity expertise are communicated in an informal and non-threatening manner.

Because the expense of conducting research in Asia is a major concern of respondents, any means by which to minimize the additional costs of biosafety and biosecurity practices will help ensure that these practices are successfully implemented. Regrettably, other problems often distract or prevent laboratories from applying appropriate biosafety and biosecurity measures. For example, respondents in *Emerging* countries also cite limited access to necessary equipment, lack of qualified staff, and difficulty in shipping infectious agents as difficulties they experience. Respondents from *Developing* countries also worry about the lack of instrumentation and complain about delayed shipments of lab supplies. While these difficulties might prove somewhat more intractable, there are obstacles that can be more readily overcome by increased communication and assistance via collaborations with Western laboratories. For instance, greater than one-third of all respondents require outside assistance with animal models. Respondents whose laboratories are located in either *Advanced* or *Emerging* countries also need support in preparing or obtaining antibodies for capture and differentiation. In contrast, respondents whose laboratories are located in *Developing* countries state that they most often need help with determining virulence-associated traits, distinguishing characteristics and diagnosis, and cultivating the infectious agents that they study. Awareness that some countries in the region are more advanced than others in implementing protocols should dictate the level of assistance offered.

APPENDIX A. STUDY METHODOLOGY

A.1 Objectives

From the perspective of researchers working with potentially hazardous biological agents, the primary objectives of this assignment will be exploratory in nature and designed to assess:

1. Types of pathogens and/or toxins used in research
2. Research objectives as they pertain to these pathogens and/or toxins
3. Laboratory capacity including tools and techniques available, personnel, physical structure
4. Status quo for biosafety and biosecurity policies and procedures
5. Perceptions of risk
6. Standards and accountability measures.

A.2 Comments

- This report, International Biosafety and Biosecurity Assessment, is based on responses to a 30-question online survey conducted by BioInformatics, LLC (Arlington, Virginia, USA).
- The questionnaire was fielded to registered members of The Science Advisory Board. Sponsored by BioInformatics, LLC, The Science Advisory Board is an online community of more than 25,000 scientists, physicians and healthcare professionals from around the world. The Science Advisory Board is divided into two panels (Research and Clinical) and "convenes" regularly via the World Wide Web (www.scienceboard.net) to voice opinions on a wide variety of issues relating to biomedical research and clinical technologies. These experts—representing all aspects of the life sciences and medicine—have agreed to make themselves available to participate in our online research activities.
- The Science Advisory Board members who participated in this study were drawn from the Board's Research Panel and supplemented by additional qualified life scientists.
- 300 scientists who study infectious agents and/or toxins in their laboratory participated in this survey between September 20 and October 22, 2005.
- Each of the qualified respondents received a personalized email message containing a unique Uniform Resource Locator (URL) directing them to the online questionnaire. The email message described the objectives of the study, the incentive for participating and a privacy guarantee.
- The online questionnaire was designed to take a maximum of 15 minutes to complete. Results were tallied automatically through a proprietary software application developed by BioInformatics and analyzed using the Statistical Package for the Social Sciences (SPSS).
- The online questionnaire consisted of 29 closed or partially close-ended questions and 1 open-ended question designed to encourage participation and to meet objectives of the study.
- Question 21 was the open-ended question. This question may be characterized by somewhat lower response rates. This may be attributable to a common tendency of respondents to skip relatively challenging questions, or a hesitancy to name a specific company when they are unsure of who is sponsoring the survey.
- In any survey, respondents will not answer some questions they deem to be irrelevant or inappropriate, or they will simply neglect to answer. This fact explains why the total number

of responses to a question is sometimes less than the total number of respondents to the survey.

- If an answer choice was not selected by any of the respondents, the answer choice may have been omitted from the analysis, rather than listing answer choices with a zero value.
- Members of The Science Advisory Board receive and accumulate “ViewPoints” as an incentive to participate in studies. Members can redeem accumulated points for items in The Science Advisory Board’s online rewards catalog. Respondents who are not members of The Science Advisory Board receive gift certificates from Amazon.com.
- The members of The Science Advisory Board represent a segment of the scientific community with a demonstrated willingness to participate in market research activities. These factors may inject a certain level of bias into the findings presented in this report, and any subsequent analysis should be viewed in this light.

A.3 Notes

- Open-ended questions with free text responses:
    - Responses such as “none,” “not applicable” or equivalent for open-ended questions were omitted from the analysis.
- Charts:
    - If any answer choice was selected by fewer than 5% of the respondents of a given question, the percent label may have been omitted from certain charts in the interests of clarity and legibility.
    - If any answer choice was selected by fewer than 1% of the respondents of a given question, the answer choice may have been omitted from certain charts in the interests of clarity and legibility.
- “Don’t know” and “Not Applicable” answer choices were omitted when calculating percentages.

A.4 Definition of terms

Below is a detailed description of some of the terms that may have been used throughout this report.

- Respondents—The total number of individuals who answered a specific question.
- Responses—The number of times a specific answer choice was mentioned. This is evident in questions that specify, “check all that apply” where the respondent can select more than one answer choice.
- Mean value (for a scale question)—A weighted arithmetic average.
- Column %—Derived by taking the numerical frequency of a particular answer choice divided by the total frequency in the relevant column.
- Row %—Derived by taking the numerical frequency of a particular answer choice divided by the total frequency in the relevant row.

For some tables, charts and cross-tabulations in this report, the following demographic information was reclassified as follows:

Geographic Region is divided into three categories, defined as follows:

- Advanced (Respondents=162) includes:
    China
    Hong Kong
    Japan
    Korea
    Singapore
    India

- Emerging (Respondents=91) includes:
    Pakistan
    Thailand
    Taiwan
    Malaysia

- Developing (Respondents=47) includes:
    Indonesia
    Cambodia
    Vietnam
    Bangladesh
    Philippines
    Sri Lanka

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