A Survey of Bioscience Research and Biosafety and Biosecurity Practices in Asia, Eastern Europe, Latin America, and the Middle East

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Abstract

In the past decade, the United States (U.S.) has enacted extensive federal legislation to regulate the possession, use, and transfer of dangerous microorganisms and toxins. Yet, few international laboratories have implemented similar safeguards. Limited data are available concerning the types of biological agents researched in non-U.S. laboratories and the biosafety and biosecurity practices employed to maintain those agents. To start addressing these knowledge gaps, an online survey was administered by BioInformatics, LLC in 2005 to 765 life scientists from 81 countries in Asia, Eastern Europe, Latin America, and the Middle East. Survey results revealed that participants are actively engaged in research with a wide variety of biological agents. Moreover, analysis of the biosafety and biosecurity data revealed several interesting findings; these findings are summarized into three major themes: biosafety is more prevalent than biosecurity, simple practices and techniques predominate, and perceptions of risk vary regionally. This survey provided unique insight into the variety of dangerous microorganisms and their toxins studied worldwide and uncovered a consistent weakness in laboratory biosafety and biosecurity. Because many of these facilities are located in volatile areas of the world, these findings indicate a potentially significant risk, and future actions are warranted to improve the safe and secure handling of biological agents internationally.

Introduction

Biosafety and biosecurity are fundamental practices that must be consistently implemented and enforced in any active bioscience research laboratory. As critical as these concepts are to the health and well-being of bioscience employees as well as the environment, an alarming lack of global awareness is associated with biosafety and biosecurity. Moreover, confusion in 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.

The World Health Organization (WHO) has been instrumental in promoting the necessity of laboratory safety since 1983, providing international guidance on basic biological safety and developing national codes of practice for the safe handling of pathogenic microorganisms in a laboratory setting. The WHO defines laboratory biosafety as "the containment principles, technologies and practices that are implemented to prevent unintentional exposure to pathogens and toxins, or their accidental release" (WHO, 2004). In 2004, the 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 similar to these WHO definitions.

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, in particular, has been a global leader in promoting laboratory biosafety and biosecurity. The United States has enacted specific legislation to regulate the possession, use, and/or transfer of Select Agents, and violations carry criminal and civil penalties. Two key U.S. laws include the USA PATRIOT Act and the Public Health Security and Bioterrorism Preparedness and Response Act of 2002. Many other countries 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 an-*

thracis, 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). While some information is available from the United States, very little is known about how non-U.S. 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 countries.

To better assess the state of international laboratory biosafety and biosecurity, Sandia National Laboratories' International Biological Threat Reduction (SNL IBTR) and BioInformatics, LLC administered an online survey to 765 scientists from 81 countries in Asia, Eastern Europe, Latin America, and the Middle East. Survey questions pertained to:

1. The level of awareness and understanding of biological risks in non-U.S. laboratories
2. The types of dangerous agents actively studied in non-U.S. laboratories
3. The types and practices of safety and security needed to maintain non-U.S. laboratories

Survey results revealed that a significant proportion of international researchers who study infectious agents practice poor biosafety and biosecurity. It is hoped that by identifying weaknesses through studies such as this, gaps in the development and implementation of biosafety and biosecurity measures can be addressed and, ultimately, overcome.

Method

Survey Participants

A cross-sectional online survey was administered to non-U.S. scientists, healthcare professionals, laboratory staff, and physicians between September 2005 and January 2007. Participants were recruited from two source populations maintained by BioInformatics, LLC. Over 47,108 scientists from Asia, Eastern Europe, Latin America, and the Middle East were invited to participate; 5,176 respondents completed the survey (response rate = 11.0%). Inclusion criteria required all participants to be actively engaged in bioscience research with at least one infectious agent and/or toxin. Respondents were excluded if they did not indicate research on an infectious agent and/or toxin, or completed less than approximately 85% of the survey.

The final analysis included an eligible sample of 765 participants from 81 countries. These individuals were categorized into two groups, *Advanced* and *Emerging/Developing*, based upon the state of their country's bioscience research infrastructure. This infrastructure was determined using secondary research which considered scientific citations per country, life scientists per capita, government investment in life science research, and the presence of biotechnology parks. Countries with the highest number of responses per region are India (Asia; 102/300 or 34.0%), Poland (Eastern Europe; 22/146 or 15.1%), Mexico (Latin America; 35/165 or 21.0%), and Iran (Middle East; 41/154 or 26.6%). More than half the respondents were from the *Advanced* countries (58.8%) and were employed in an academic field (56.6%) as professors or teachers (32.2%). Basic research was the most frequently cited type of laboratory research conducted by participants from all regions (43.4%). Additional demographic information is summarized and provided in Table 1.

Survey

The online survey was developed to assess international biosafety and biosecurity practices. Each survey consisted of 30 questions, including 29 closed or partially closed questions and 1 open-ended question. Qualified scientists from each region were contacted by e-mail and instructed to access the questionnaire online. Survey questions focused on:

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

The nearly universally recognized WHO *Laboratory Biosafety Manual* was used as the reference point for definitions of biosafety levels and other terms in an attempt to mitigate the diversity of terminologies which refer to different degrees of containment laboratories and different ways of implementing those controls.

The survey also collected information regarding participant demographics. Each survey was designed to take no more than 15 minutes to complete and guaranteed privacy to the respondent. Surveys were translated into English, Spanish, Russian, and Arabic. As encouragement for participation, participants were awarded redeemable points or a U.S. $10 honorarium.

Survey Analysis

Survey results in each region were tallied and analyzed by BioInformatics, LLC using a commercial software package, *Statistical Package for Social Sciences* (SPSS) (SPSS Inc., Chicago, Illinois). The response rate for each question varied as not all respondents answered the survey completely. All unanswered questions were treated as missing values in the analysis.

Organization of This Paper

Most of the respondents' laboratories perform various types of research and work on multiple types of

Table 1

Demographic factors of survey participants by response status (n [%]).

	Asia (n=300)	Eastern Europe (n=146)	Latin America (n=165)	Middle East (n=154)	Total (n=765)
Survey					
TOTAL INVITED	17,786	10,211	8,128	10,983	47,108
Responded	1031 (5.8%)	1455 (14.2%)	879 (11.1%)	1811 (16.5%)	5176 (11.0%)
Eligible participants	300	146	165	154	765
Ineligible participants and/or incomplete surveys	731	1,309	714	1657	4,411
Representative Countries					
TOTAL	16	21	19	25	81
Advanced countries	6 (37.5%)	6 (28.6%)	7 (36.8%)	8 (32.0%)	27 (33.3%)
Emerging/developing countries	10 (62.5%)	15 (71.4%)	12 (63.2%)	17 (68.0%)	54 (66.7%)
TOTAL RESPONSES	300	146	165	154	765
Advanced countries	162 (54.0%)	73 (50%)	117 (70.9%)	98 (63.6%)	450 (58.8%)
Emerging/developing countries	138 (46.0%)	73 (50%)	48 (29.1%)	56 (36.4%)	315 (41.2%)
Educational Level					
TOTAL RESPONSES	279	145	164	152	740
Bachelors degree	13 (4.7%)	2 (1.4%)	10 (6.1%)	8 (5.3%)	33 (4.5%)
Masters degree	63 (22.6%)	20 (13.8%)	37 (22.6%)	12 (7.9%)	132 (17.8%)
Doctoral degree	200 (71.7%)	123 (84.8%)	116 (70.7%)	132 (86.8%)	571 (77.2%)
Scientific Field					
TOTAL RESPONSES	277	145	164	154	740
Academic	138 (50.0%)	84 (57.9%)	96 (58.5%)	101 (65.6%)	419 (56.6%)
Government	46 (16.6%)	25 (17.2%)	36 (22.0%)	14 (9.1%)	121 (16.4%)
Hospital or medical center	34 (12.3%)	14 (9.7%)	12 (7.3%)	20 (13.0%)	80 (10.8%)
Pharmaceutical/biotechnology	28 (10.1%)	0	5 (3.0%)	3 (1.9%)	36 (4.9%)
Employment Position					
TOTAL RESPONSES	282	146	164	154	746
Lab director/supervisor	46 (16.3%)	39 (26.7%)	39 (23.8%)	19 (12.3%)	143 (19.2%)
Professor/teacher	86 (30.5%)	37 (25.3%)	36 (22.0%)	81 (52.6%)	240 (32.2%)
Staff scientist	20 (7.1%)	24 (16.4%)	15 (9.1%)	13 (8.4%)	72 (9.7%)
Principal investigator	60 (21.3%)	22 (15.1%)	55 (33.5%)	15 (9.7%)	152 (20.4%)
Type of Research Conducted in Laboratory					
TOTAL RESPONSES	296	145	164	153	758
Basic	115 (38.9%)	73 (50.3%)	85 (51.8%)	56 (36.6%)	329 (43.4%)
Disease surveillance	54 (18.2%)	25 (17.2%)	41 (25%)	25 (16.3%)	145 (19.1%)
Clinical	56 (19.0%)	24 (16.6%)	22 (13.4%)	52 (34.0%)	154 (20.3%)
Drug discovery and/or development	57 (19.3%)	20 (13.8%)	9 (5.5%)	13 (8.5%)	99 (13.1%)
Work Activities Using Infectious Agents and/or Toxins					
TOTAL RESPONSES	276	143	162	152	733
Conduct "hands-on" research	108 (39.1%)	46 (32.2%)	70 (43.2%)	42 (27.6%)	266 (36.3%)
Supervise research	118 (42.8%)	58 (40.6%)	66 (40.7%)	74 (48.7%)	316 (43.1%)
Analyze data only	25 (9.1%)	25 (17.5%)	14 (8.6%)	22 (14.5%)	86 (11.7%)

pathogens; therefore, the participants' survey responses are not research- or pathogen-specific. Rather, they reflect the cumulative or highest biosafety and biosecurity practices used throughout the laboratory. For example, a laboratory that primarily researches *Salmonella* at Biosafety Level 1 (BSL-1) might select Biosafety Level 3 (BSL-3) and other more stringent biosafety practices because a small proportion of its work is done with more dangerous pathogens. To better understand the research and type of pathogen-specific biosafety and biosecurity practices, the authors separated the respondents into two major categories based on their laboratory's type of research and type of pathogen studied. This strategy removed all respondents who worked on more than one type of pathogen and in more than one research area.

Five research stages were considered: basic, clinical, disease surveillance, drug discovery, and translational research. Similarly, four types of pathogen research were considered: food-borne (*Escherichia coli* O157:H7, *Salmonella typhi*, *Shigella dysenteriae*, and *Vibrio cholerae*), emerging (highly pathogenic avian influenza [AI] virus A (H5N1), Hantaan virus, and severe acute respiratory syndrome coronavirus [SARS-CoV]), blood-borne (dengue fever viruses 1-4, human immunodeficiency virus type 1 [HIV-1], rabies virus, and *Plasmodium sp.*), and agents that pose an inhalational risk (SARS-CoV, *Brucella abortus*, *melitensis* or *suis*, *Chlamydophila psittaci*, *Francisella tularensis*, and *Mycobacterium tuberculosis*).

The survey consisted of simple yes/no or multiple choice questions to aid in data normalization. Tables 1-3 show the results of these analyses. The Biosecurity and Risk Perception portion of the survey uses a 5- and 7-point scale, respectively. The 5-point scale captures frequency of use (1=None of the time, 2=Little of the time, 3=Some of the time, 4=Most of the time, 5=All of the time), and the 7-point scale assesses severity of risk (1=Very Unconcerned/Very Unlikely, 7=Very Worried/Very Likely). Survey results are presented as a regional and overall average (Tables 4-5). This paper highlights and discusses only select biosafety and biosecurity practices and perceptions of risk in the sample population. The full results of the survey are published in *SAND Report 2009-0868* available at: www.biosecurity.sandia.gov.

Results

Infectious Microorganisms and Toxins

Respondents represent such diverse fields as virology, microbiology, toxicology, and pathology and perform research on a wide variety of organisms. In general, respondents study bacteria and viruses more frequently than they study toxins. Bacteriology predominates in most areas; however, viruses are studied most often in Latin America. Regional variations in pathogen research presumably exist as a result of the epidemiological differences of endemic diseases and public health threats. Following are the most frequently studied agents and toxins common to each region.

The most commonly investigated pathogens and toxins overall are:

- *Escherichia coli* O157:H7
- *Salmonella typhi*
- *Shigella dysenteriae*
- Human immunodeficiency virus (HIV)
- *Staphylococcus aureus* toxin

In all regions, *Escherichia coli* O157:H7, *Salmonella typhi*, and *Shigella dysenteriae* are the three most frequently studied bacterial strains. *Mycobacterium tuberculosis* is a commonly researched pathogen in the Eastern European, Latin American, and the Middle Eastern regions, while *Vibrio cholerae* is the third most frequently studied infectious bacteria in Asia.

HIV is the most frequently studied virus in all regions. Other virus research varies widely. For instance, the large majority of Middle Eastern viral researchers study hepatitis viruses (70%) compared to just 14% of the Asian researchers. Yet Asia investigates SARS, highly pathogenic avian influenza, and dengue fever much more frequently than any other region.

Toxins and parasites were the least studied agents. Most respondents investigate *Staphylococcus aureus* toxins and malaria more than any other toxin or parasite. Botulinum toxin and *Clostridium perfringens* toxin were generally the second and third most researched toxins. In some Latin American regions, parasites such as *Trypanosoma cruzi*, the cause of the Chagas' disease, are routinely studied. It is also important to note that up to 77% of researchers also reported working on biological agents and/or toxins not listed on the questionnaire. In these cases, respondents were able to select "Other" and list alternate agents researched in their laboratories.

Biosafety Practices

Personal protective equipment (PPE) is the most consistently used biosafety practice in all regions (Tables 2a-2b). Gloves, gowns, and lab coats are the most common PPE and are routinely worn 72%-94% of the time. Face shields and goggles are also common but used less frequently. Biosafety cabinets (BSC) and the presence of an autoclave within the laboratory are also fairly common in many of the respondents' labs. More sophisticated biosafety practices, such as the ability to monitor people using closed circuit television and two-way communication, are the least employed practices. Other measures, such as building ventilation systems and effluent waste decontamination systems, are used sporadically in many regions. Detailed data were not collected on specific biosafety practices or on validation mechanisms of engineering controls.

Table 2a

Frequency of select biosafety practices (%).

	Monitor w/Window	Monitor w/CC TV	Monitor w/2-way Communication	BSC	Gowns, Lab Coats	Gloves	Face Shield, Goggles	Onsite Autoclave	Lab Autoclave	Inward Ventilation	Controlled Ventilation	HEPA Ventilation	Waste Decontamination
Basic Research													
Asia (n=111)	27.9	4.5	20.7	54.0	84.7	82.9	51.4	46.9	54.1	26.1	30.6	43.2	67.6
Eastern Europe (n=73)	27.4	1.4	12.3	46.6	83.6	87.7	49.3	39.7	49.3	38.4	32.9	21.9	42.5
Latin America (n=85)	51.8	4.7	11.8	64.7	88.2	91.8	61.2	37.7	58.8	31.8	28.2	21.2	51.8
Middle East (n=60)	33.3	3.3	18.3	60.0	90.0	88.3	56.7	50.0	48.3	26.7	36.7	26.7	53.3
AVERAGE	**35.1**	**3.5**	**15.8**	**56.3**	**86.6**	**87.7**	**54.7**	**43.6**	**52.6**	**30.8**	**32.1**	**28.3**	**53.8**
Clinical Research													
Asia (n=52)	48.1	19.2	32.7	61.5	80.8	80.8	53.9	55.8	34.6	30.8	30.8	38.5	57.7
Eastern Europe (n=24)	33.3	12.5	20.8	41.7	70.8	83.3	58.3	45.8	29.2	29.2	41.7	20.8	29.2
Latin America (n=21)	57.1	4.8	23.8	71.4	95.2	85.7	71.4	61.9	52.4	47.6	52.4	9.5	38.1
Middle East (n=56)	32.1	8.9	21.4	37.5	73.2	80.4	55.4	42.9	48.2	33.9	28.6	30.4	44.6
AVERAGE	**42.7**	**11.4**	**24.7**	**53.0**	**80.0**	**82.6**	**59.8**	**51.6**	**41.1**	**35.4**	**38.4**	**24.8**	**42.4**
Disease Surveillance Research													
Asia (n=53)	49.1	11.3	26.4	60.4	79.3	79.3	62.3	50.9	37.7	37.7	28.3	39.6	71.7
Eastern Europe (n=25)	37.5	4.2	25.0	79.2	91.7	87.5	83.3	37.5	54.2	16.7	50.0	54.2	54.2
Latin America (n=41)	61.0	7.3	17.1	68.3	95.1	85.4	68.3	48.8	56.1	24.4	39.0	31.7	63.4
Middle East (n=26)	38.5	0.0	23.1	53.9	88.5	88.5	57.7	57.7	50.0	30.8	42.3	15.4	50.0
AVERAGE	**46.5**	**5.7**	**22.9**	**65.5**	**88.7**	**85.2**	**67.9**	**48.7**	**49.5**	**27.4**	**39.9**	**35.2**	**59.8**
Drug Discovery Research													
Asia (n=56)	46.4	19.6	30.4	71.4	83.9	83.9	67.9	53.6	41.1	37.5	50.0	57.1	67.9
Eastern Europe (n=20)	35.0	0.0	20.0	60.0	90.0	95.0	65.0	60.0	45.0	35.0	40.0	40.0	35.0
Latin America (n=9)	55.6	0.0	11.1	66.7	88.9	88.9	88.9	11.1	77.8	44.4	22.2	11.1	44.4
Middle East (n=14)	57.1	7.1	21.4	57.1	71.4	85.7	57.1	57.1	42.9	35.7	42.9	35.7	28.6
AVERAGE	**48.5**	**6.7**	**20.7**	**63.8**	**83.6**	**88.4**	**69.7**	**45.5**	**51.7**	**38.2**	**38.8**	**36.0**	**44.0**
Translational Research													
Asia (n=12)	8.3	16.7	16.7	66.7	91.7	91.7	66.7	58.3	66.7	16.7	50.0	58.3	83.3
Eastern Europe (n=3)	0.0	0.0	0.0	33.3	66.7	66.7	100.0	33.3	33.3	66.7	0.0	0.0	33.3
Latin America (n=7)	42.9	0.0	0.0	57.1	85.7	100.0	100.0	42.9	42.9	14.3	28.6	28.6	57.1
Middle East (n=8)	50.0	12.5	0.0	37.5	87.5	87.5	50.0	50.0	25.0	25.0	50.0	12.5	25.0
AVERAGE	**25.3**	**7.3**	**4.2**	**48.7**	**82.9**	**86.5**	**79.2**	**46.1**	**42.0**	**30.7**	**32.2**	**24.9**	**49.7**

A review of biosafety level practices revealed two significant findings. First, the majority of respondents work in a BSL-2 setting (Tables 3a-3b); this is consistent across all regions. However, some research is performed in BSL-1 and BSL-3 facilities. BSL-1 is used most frequently in food-borne pathogen research, while much of the emerging, blood-borne, and inhalational pathogen research is performed in a BSL-3. The most alarming finding, however, is that a significant proportion of the respondents claim they do not know at what biosafety level they currently work with their infectious agent or toxin. This was the most common response from the Middle Eastern participants.

Biosecurity Practices

Biosecurity is inconsistently employed around the world. Physical security to reduce the risk of unauthorized access to a laboratory is relatively weak in nearly every region. The most widespread biosecurity measures include locked laboratory doors, locked building doors,

Table 2b

Frequency of select biosafety practices (%).

	Monitor w/Window	Monitor w/CC TV	Monitor w/2-way Communication	BSC	Gowns, Lab Coats	Gloves	Face Shield, Goggles	Onsite Autoclave	Lab Autoclave	Inward Ventilation	Controlled Ventilation	HEPA Ventilation	Waste Decontamination
Food-borne Pathogens													
Asia (n=31)	35.5	6.5	12.9	58.1	77.4	80.7	54.8	45.2	48.4	12.9	38.7	35.5	64.5
Eastern Europe (n=10)	50.0	10.0	0.0	50.0	100.0	100.0	30.0	60.0	30.0	40.0	40.0	50.0	40.0
Latin America (n=12)	58.3	0.0	8.3	75.0	91.7	100.0	83.3	50.0	50.0	33.3	16.7	33.3	50.0
Middle East (n=13)	69.2	7.7	23.1	69.2	84.6	92.3	84.6	84.6	23.1	30.8	30.8	38.5	61.5
AVERAGE	**53.3**	**6.1**	**11.1**	**63.1**	**88.4**	**93.3**	**63.2**	**60.0**	**37.9**	**29.3**	**31.6**	**39.3**	**54.0**
Emerging Pathogens													
Asia (n=6)	66.7	16.7	16.7	83.3	66.7	66.7	50.0	50.0	33.3	16.7	50.0	66.7	50.0
Eastern Europe (n=2)	33.3	0.0	0.0	33.3	66.7	66.7	66.7	33.3	0.0	33.3	33.3	33.3	33.3
Latin America (n=3)	33.3	0.0	0.0	66.7	100.0	100.0	100.0	66.7	33.3	66.7	0.0	33.3	66.7
Middle East (n=1)	0.0	0.0	0.0	0.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0
AVERAGE	**33.3**	**4.2**	**4.2**	**45.8**	**83.4**	**83.4**	**79.2**	**62.5**	**16.7**	**29.2**	**20.8**	**33.3**	**37.5**
Blood-borne Pathogens													
Asia (n=17)	52.9	5.9	29.4	70.6	88.2	88.2	47.1	64.7	23.5	17.7	29.4	52.9	82.4
Eastern Europe (n=2)	0.0	0.0	0.0	100.0	100.0	100.0	100.0	50.0	100.0	0.0	0.0	50.0	50.0
Latin America (n=8)	87.5	12.5	25.0	75.0	100.0	87.5	62.5	12.5	75.0	25.0	62.5	25.0	62.5
Middle East (n=1)	100.0	0.0	0.0	100.0	0.0	100.0	100.0	0.0	100.0	0.0	100.0	0.0	0.0
AVERAGE	**60.1**	**4.6**	**13.6**	**86.4**	**72.1**	**93.9**	**77.4**	**31.8**	**74.6**	**10.7**	**48.0**	**32.0**	**48.7**
Pathogens Posing an Inhalational Risk													
Asia (n=5)	60.0	20.0	0.0	80.0	60.0	60.0	40.0	40.0	40.0	0.0	40.0	60.0	40.0
Eastern Europe (n=5)	60.0	0.0	20.0	20.0	100.0	100.0	80.0	0.0	80.0	0.0	60.0	60.0	20.0
Latin America (n=6)	66.7	0.0	0.0	100.0	83.3	100.0	50.0	16.7	83.3	50.0	16.7	16.7	16.7
Middle East (n=7)	57.1	0.0	14.3	57.1	100.0	100.0	71.4	28.6	100.0	14.3	71.4	28.6	85.7
AVERAGE	**61.0**	**5.0**	**8.6**	**64.3**	**85.8**	**90.0**	**60.4**	**21.3**	**75.8**	**16.1**	**47.0**	**41.3**	**40.6**

Tables 3a and 3b

The biosafety level most commonly used when working with infectious agents and/or toxins (%).

Table 3a	BSL-1	BSL-2	BSL-3	BSL-4	Don't Know
Basic Research					
Asia (n=109)	22.9	51.4	10.1	—	15.6
Eastern Europe (n=72)	22.2	27.8	6.9	—	43.1
Latin America (n=82)	17.1	52.4	12.2	—	18.3
Middle East (n=58)	17.2	29.3	5.2	1.7	46.6
Clinical Research					
Asia (n=48)	12.5	47.9	16.7	—	22.9
Eastern Europe (n=23)	13	52.2	4.4	—	30.4
Latin America (n=21)	4.8	52.4	9.5	—	33.3
Middle East (n=54)	9.3	37.0	11.1	1.9	40.7
Disease Surveillance Research					
Asia (n=50)	16.0	52.0	18.0	2.0	12.0
Eastern Europe (n=25)	4.0	32.0	24.0	12.0	28.0
Latin America (n=40)	10.0	62.5	20.0	—	7.5
Middle East (n=25)	12.0	32.0	16.0	—	40.0
Drug Discovery Research					
Asia (n=54)	16.7	37.0	18.5	1.9	25.9
Eastern Europe (n=20)	20.0	45.0	10.0	—	25.0
Latin America (n=9)	44.4	33.3	11.1	—	11.1
Middle East (n=14)	7.1	42.9	—	—	50.0
Translational Research					
Asia (n=11)	18.2	36.4	18.2	—	27.3
Eastern Europe (n=3)	—	100	—	—	—
Latin America (n=6)	—	33.3	16.7	—	50.0
Middle East (n=8)	25.0	37.5	—	12.5	25.0

Table 3b	BSL-1	BSL-2	BSL-3	BSL-4	Don't Know
Food-borne Pathogens					
Asia (n=28)	25.0	35.7	7.1	—	32.1
Eastern Europe (n=10)	40.0	30.0	—	—	30.0
Latin America (n=12)	25.0	50.0	—	—	25.0
Middle East (n=13)	15.4	46.2	—	7.7	30.8
Emerging Pathogens					
Asia (n=5)	—	60.0	40.0	—	—
Eastern Europe (n=2)	—	66.7	33.3	—	—
Latin America (n=3)	—	66.7	33.3	—	—
Middle East (n=1)	—	100.0	—	—	—
Blood-borne Pathogens					
Asia (n=17)	5.9	41.2	35.3	—	17.7
Eastern Europe (n=2)	50.0	50.0	—	—	—
Latin America (n=8)	12.5	50.0	37.5	—	—
Middle East (n=1)	—	—	—	—	100.0
Pathogens Posing an Inhalational Risk					
Asia (n=4)	—	75.0	25.0	—	—
Eastern Europe (n=5)	20.0	—	40.0	—	40.0
Latin America (n=6)	33.3	16.7	50.0	—	—
Middle East (n=7)	—	28.6	57.1	—	14.3

and locked cabinets; less routinely researchers lock their refrigerators. Yet, in some areas, even these simple measures are not regularly implemented. More sophisticated physical security measures are used by a smaller proportion of respondents. These may include implementation of more technological measures or other advanced practices used to mitigate the risk of biological theft from a laboratory. In all categories, the use of video monitors, sensors and alarms, and self-closing doors are rarely used. Other practices vary extensively (Tables 4a-4b).

Personnel security is the principal measure for addressing the risk that a lab worker with legitimate access may steal or misuse a biological agent (Salerno & Gaudioso, 2007). For respondents, personnel security

Table 4a

Physical Security Practices*

	Access Control Devices	Entry Building Guard	Sensors and Alarms	Lit Building at Night	Locked Cabinets	Locked Building Doors	Locked Lab Doors	Locked Fridges	Security Patrols	Self-closing Doors	Unobstructed View	Video Monitors
Basic Research												
Asia (n=105)	3.4	3.2	2.8	3.6	3.7	3.7	4.0	3.4	3.2	3.1	3.4	2.2
Eastern Europe (n=69)	3.3	3.9	3.2	3.2	3.9	3.9	3.8	3.0	2.5	2.2	2.6	1.9
Latin America (n=79)	3.5	3.6	2.2	4.0	3.9	4.0	4.2	3.5	2.6	2.7	3.6	1.8
Middle East (n=58)	3.4	3.9	2.7	3.9	3.9	3.9	4.4	3.0	3.2	2.9	2.8	1.6
AVERAGE	**3.4**	**3.6**	**2.7**	**3.7**	**3.8**	**3.9**	**4.1**	**3.2**	**2.9**	**2.7**	**3.1**	**1.9**
Clinical Research												
Asia (n=46)	3.6	3.8	2.2	4.0	4.0	4.0	4.4	3.6	3.2	3.1	3.3	2.5
Eastern Europe (n=24)	3.5	3.1	3.1	4.0	4.1	4.1	3.9	3.3	2.9	2.2	2.8	2.3
Latin America (n=21)	3.7	3.4	2.2	3.8	4.0	4.0	4.4	3.9	2.9	3.5	3.3	1.7
Middle East (n=53)	3.2	3.7	2.4	3.3	3.6	3.6	3.8	3.1	3.3	2.6	2.6	1.8
AVERAGE	**3.5**	**3.5**	**2.5**	**3.8**	**3.9**	**3.9**	**4.1**	**3.5**	**3.1**	**2.8**	**3.0**	**2.1**
Disease Surveillance Research												
Asia (n=50)	3.8	4.0	3.0	3.9	3.9	4.2	4.1	3.6	3.8	3.1	4.0	2.7
Eastern Europe (n=24)	3.5	3.1	3.1	4.0	4.1	4.1	3.9	3.3	2.9	2.2	2.8	2.3
Latin America (n=40)	3.3	3.8	1.8	3.9	3.9	3.9	4.2	4.2	2.6	2.9	3.3	1.6
Middle East (n=24)	3.3	4.1	3.0	3.2	3.7	3.8	4.0	3.0	3.4	2.8	2.9	2.0
AVERAGE	**3.6**	**4.0**	**2.8**	**3.6**	**3.9**	**4.1**	**4.2**	**3.8**	**3.2**	**3.1**	**3.6**	**2.2**
Drug Discovery Research												
Asia (n=51)	4.1	4.3	3.5	3.9	4.1	3.9	4.1	3.5	3.6	4.0	3.8	2.6
Eastern Europe (n=20)	3.9	4.4	3.1	4.4	4.3	4.1	4.4	3.5	3.4	2.6	2.9	2.8
Latin America (n=9)	3.5	4.5	2.1	4.4	4.6	4.9	4.4	3.9	3.4	2.1	3.3	1.6
Middle East (n=12)	4.3	4.2	3.1	3.3	4.5	3.9	4.3	4.4	3.1	3.2	3.6	1.9
AVERAGE	**4.0**	**4.4**	**3.0**	**4.0**	**4.4**	**4.2**	**4.3**	**3.8**	**3.4**	**3.0**	**3.4**	**2.2**
Translational Research												
Asia (n=12)	3.1	4.1	3.4	4.5	4.6	4.5	4.3	3.6	3.6	3.3	3.5	2.6
Eastern Europe (n=3)	4.7	3.3	2.7	4.0	4.0	4.0	4.3	2.3	2.3	1.0	3.3	1.7
Latin America (n=7)	4.0	4.1	3.5	4.3	3.8	3.6	4.3	3.0	2.5	2.3	2.8	2.8
Middle East (n=8)	2.3	4.4	2.8	3.7	4.7	4.1	4.3	4.0	3.9	2.0	3.5	1.7
AVERAGE	**3.5**	**4.0**	**3.1**	**4.1**	**4.3**	**4.1**	**4.3**	**3.2**	**3.1**	**2.2**	**3.3**	**2.2**

*This question was answered on a 5-point scale: 5=All of the time; 4=Most of the time; 3=Some of the time; 2=Little of the time; 1=None of the time. The above scores are an average of the respondents' results.

most typically involves biosecurity training for new employees, restricted access to laboratory areas, and lists of employees who have access to restricted areas. Overall, personnel security measures are even less consistently applied than physical security measures. Photo identification badges, building escorts, biosecurity training, and background screening of potential new employees are infrequently implemented. Generally, basic and clinical labs have very poor personnel security, with more advanced laboratories implementing more security measures.

Information security, a set of tools and practices used to protect sensitive information, is no less varied. In all regions, password protection of computers and files is the most frequent information security measure. In contrast, storage of important hard copies of information (including paper, tapes, and videos) in secure containers is the least practiced measure within each region and category. Lastly, Material Control and Accountability (MC&A) measures help enhance laboratory biosecurity by establishing exactly what biological material is present at a facility, how and where the material is stored and handled, and who is responsible for it (Salerno & Gaudioso, 2007). Overall, MC&A is generally quite robust within each region as nearly all of the practices are used most to all of the time. The laboratory head or direct supervisor was the most commonly identified person to account for a laboratory's pathogens and toxins.

Table 4b

Physical Security Practices*

	Access Control Devices	Entry Building Guard	Sensors and Alarms	Lit Building at Night	Locked Cabinets	Locked Building Doors	Locked Lab Doors	Locked Fridges	Security Patrols	Self-closing Doors	Unobstructed View	Video Monitors
Food-borne Pathogens												
Asia (n=28)	3.7	3.8	3.0	4.2	4.3	4.3	4.4	3.6	3.5	3.1	3.4	2.5
Eastern Europe (n=9)	4.1	4.7	3.0	4.7	4.0	4.0	4.2	3.8	2.2	2.7	2.5	2.4
Latin America (n=11)	3.1	2.6	2.1	3.4	3.6	3.7	4.0	3.0	2.5	2.7	3.4	1.5
Middle East (n=12)	3.5	4.4	4.0	4.8	4.6	4.2	4.6	4.1	4.1	3.9	4.1	2.6
AVERAGE	**3.6**	**3.9**	**3.0**	**4.3**	**4.1**	**4.1**	**4.3**	**3.6**	**3.1**	**3.1**	**3.4**	**2.3**
Emerging Pathogens												
Asia (n=6)	4.0	3.8	3.5	3.3	3.0	2.4	3.6	3.8	3.7	3.7	3.3	2.8
Eastern Europe (n=2)	5.0	5.0	5.0	4.5	4.0	4.5	4.0	5.0	4.5	1.0	5.0	1.0
Latin America (n=3)	2.7	2.3	1.3	2.0	2.0	3.0	2.3	1.7	1.7	2.3	1.5	1.0
Middle East (n=1)	1.0	5.0	1.0	1.0	1.0	5.0	5.0	1.0	5.0	1.0	5.0	1.0
AVERAGE	**3.2**	**4.0**	**2.7**	**2.7**	**2.5**	**3.7**	**3.7**	**2.9**	**3.7**	**2.0**	**3.7**	**1.5**
Blood-borne Pathogens												
Asia (n=16)	3.4	3.9	2.1	3.4	3.8	3.6	3.8	2.8	3.3	2.5	3.3	1.8
Eastern Europe (n=2)	4.5	4.5	1.0	2.5	4.0	4.0	4.5	2.5	2.0	3.5	1.0	3.0
Latin America (n=8)	3.6	3.1	1.1	3.1	3.4	4.4	4.8	3.5	1.4	2.0	2.3	1.9
Middle East (n=1)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.0
AVERAGE	**3.4**	**3.4**	**1.6**	**2.8**	**3.3**	**3.5**	**3.8**	**2.7**	**2.2**	**2.5**	**2.2**	**1.9**
Pathogens Posing an Inhalational Risk												
Asia (n=5)	3.8	3.6	3.2	3.0	3.4	2.8	3.3	3.6	3.4	3.4	3.0	3.2
Eastern Europe (n=5)	3.0	3.8	3.0	3.6	2.8	4.3	4.0	3.0	4.7	3.0	4.0	2.0
Latin America (n=6)	2.8	3.5	1.7	4.2	3.0	4.8	3.5	2.8	3.5	2.2	3.8	1.2
Middle East (n=7)	4.2	4.4	2.2	4.0	4.2	4.0	4.6	2.5	3.7	3.2	4.6	2.2
AVERAGE	**3.5**	**3.8**	**2.5**	**3.7**	**3.3**	**4.0**	**3.8**	**3.0**	**3.8**	**3.0**	**3.9**	**2.2**

*This question was answered on a 5-point scale: 5=All of the time; 4=Most of the time; 3=Some of the time; 2=Little of the time; 1=None of the time. The above scores are an average of the respondents' results.

Risk Perceptions

When asked about the respondent's degree of concern for various scenarios involving infectious agents and/or toxins that his/her laboratory studies, the most commonly cited concerns for most categories included *Accidentally infecting people or animals or contaminating the environment outside the laboratory* and *Laboratory-acquired infections* (Table 5a). Yet, respondents researching emerging pathogens often selected *Becoming more virulent* and *Acquiring ability to infect new species* as highly likely (i.e., a 5.8 and 6.2 average, respectively, on a 7-point scale where 7=Very worried).

Overall, being *Repurposed by government to serve as a public health lab (e.g., diagnostics, vaccinations, etc.) during an epidemic* was a significant concern in all regions. This was especially a concern in Asian, Eastern European, and Latin American laboratories doing disease surveillance work (Table 6a). Yet, when asked about the likelihood that their laboratory could be involved in or affected by *Theft of samples with the intent to do harm* by either an employee or a non-employee (outsider), the overwhelming majority of respondents claimed this was a remote possibility (Table 6b). This was consistent among both categories and across all regions.

Table 5a

Risk perceptions of various scenarios involving an infectious agent or toxin that a respondent's laboratory studies by research type.*

	Accidentally Infecting People/Animals/ or Environment	Acquire Ability to Infect New Species	Agent or Toxin Could Be Used to Cause Harm	Become More Virulent	Laboratory-acquired Infection
Basic Research					
Asia (n=105)	5.4	5.0	5.0	4.8	5.0
Eastern Europe (n=71)	3.5	3.0	3.4	3.1	3.9
Latin America (n=81)	5.6	4.5	4.4	4.6	5.2
Middle East (n=58)	5.0	4.3	4.5	4.4	5.0
AVERAGE	**4.9**	**4.2**	**4.3**	**4.2**	**4.8**
Clinical Research					
Asia (n=45)	5.6	5.1	5.2	5.2	5.8
Eastern Europe (n=24)	4.8	4.1	4.0	4.5	4.7
Latin America (n=21)	5.7	5.0	5.4	5.2	6.0
Middle East (n=51)	5.0	4.4	4.3	4.4	4.9
AVERAGE	**5.3**	**4.7**	**4.7**	**4.8**	**5.4**
Disease Surveillance Research					
Asia (n=48)	5.6	5.2	5.5	5.2	5.8
Eastern Europe (n=22)	5.1	5.0	4.9	5.1	5.6
Latin America (n=40)	5.4	4.6	4.6	4.5	5.6
Middle East (n=25)	5.5	4.8	5.0	4.7	5.3
AVERAGE	**5.4**	**4.9**	**5.0**	**4.9**	**5.6**
Drug Discovery Research					
Asia (n=51)	5.3	4.7	5.0	5.1	5.1
Eastern Europe (n=17)	5.0	4.4	4.6	4.7	5.2
Latin America (n=9)	6.0	5.9	5.9	5.7	6.2
Middle East (n=11)	5.4	4.8	5.4	4.8	5.7
AVERAGE	**5.4**	**4.9**	**5.2**	**5.1**	**5.6**
Translational Research					
Asia (n=12)	5.5	5.5	5.2	5.4	5.3
Eastern Europe (n=3)	3.3	3.3	4.7	4.0	3.3
Latin America (n=7)	5.7	5.2	4.5	3.8	4.7
Middle East (n=8)	6.1	5.4	5.1	5.5	6.0
AVERAGE	**5.2**	**4.8**	**4.9**	**4.7**	**4.8**

*This question was answered on a 7-point scale: 7=very worried; 1=very unconcerned. The above scores are an average of the respondents' results.

Discussion

This survey sought to gather insight into the status of international laboratory biosafety and biosecurity in Asia, Eastern Europe, Latin America, and the Middle East. The survey engaged 765 international life scientists who actively study infectious agents and/or toxins. Specific objectives of the survey include identifying the types of pathogens and/or toxins used in research, research objectives, laboratory capacity, the status quo for biosafety and biosecurity policies and procedures, perceptions of risk, and standards and accountability measures. Results of the analysis identified three major themes:

1. Biosafety is more prevalent than biosecurity.
2. Simple practices and techniques predominate.
3. Perceptions of risk vary regionally.

Biosafety is More Prevalent than Biosecurity

Biosafety is implemented, to varying extents, in every region included in this survey. A primary reason respondents may employ biosafety is to reduce the risk of accidentally infecting themselves while working with infectious pathogens. This concern is likely the principal reason why personal biosafety—in the form of lab coats, gloves, and safety goggles—is relatively universal. Interestingly, although personal safety might be important to the respondents, environmental safety is not, as just one-third to one-half of respondents routinely decontaminate their waste, and roughly one-quarter to one-third use controlled ventilation. Evidence also suggests that for many, a known risk that cannot be mitigated will result in work not being conducted, as approximately 50%-80% of respondents claim that if they do not have a particular piece of laboratory safety equipment neces-

Table 5b

Risk perceptions of various scenarios involving an infectious agent or toxin that a respondent's laboratory studies by research type.*

	Accidentally Infecting People/Animals/ or Environment	Acquire Ability to Infect New Species	Agent or Toxin Could Be Used to Cause Harm	Become More Virulent	Laboratory-acquired Infection
Food-borne Pathogens					
Asia (n=27)	5.7	5.4	5.5	5.3	5.8
Eastern Europe (n=7)	3.6	3.6	3.6	3.4	3.6
Latin America (n=12)	6.3	5.3	4.8	5.3	5.4
Middle East (n=12)	4.3	4.7	3.9	4.7	4.9
AVERAGE	**5.0**	**4.7**	**4.5**	**4.7**	**4.9**
Emerging Pathogens					
Asia (n=6)	4.0	3.7	3.7	4.2	4.3
Eastern Europe (n=2)	6.0	7.0	4.0	6.0	6.0
Latin America (n=3)	7.0	7.0	6.7	6.0	6.0
Middle East (n=1)	1.0	7.0	1.0	7.0	1.0
AVERAGE	**4.5**	**6.2**	**3.8**	**5.8**	**4.3**
Blood-borne Pathogens					
Asia (n=15)	5.5	4.3	4.7	4.7	4.5
Eastern Europe (n=1)	1.0	1.0	5.0	1.0	7.0
Latin America (n=8)	5.4	4.0	4.1	3.8	5.9
Middle East (n=1)	3.0	3.0	3.0	3.0	3.0
AVERAGE	**3.7**	**3.1**	**4.2**	**3.1**	**5.1**
Pathogens Posing an Inhalational Risk					
Asia (n=5)	3.6	3.6	3.4	3.6	3.8
Eastern Europe (n=5)	3.2	2.2	2.6	2.4	3.8
Latin America (n=5)	4.8	3.4	5.0	4.6	5.2
Middle East (n=7)	5.7	5.0	5.3	4.9	5.6
AVERAGE	**4.3**	**3.6**	**4.1**	**3.9**	**4.6**

*This question was answered on a 7-point scale: 7=very worried; 1=very unconcerned. The above scores are an average of the respondents' results.

sary to perform an experiment, they will *not* perform the experiment. However, what a respondent deems as "necessary equipment" is most likely influenced by his/her prior laboratory experience. In addition, respondents' organizations use a variety of different means to manage their biosafety and biosecurity programs. The most commonly used methods are a biosafety operations manual, an institutional biosafety committee, biosafety training procedures, and a laboratory management plan, although biosecurity programs are not frequently used. Biosecurity issues also do not figure as predominantly in most of the respondents' risk assessments.

Nevertheless, other biosafety practices, which are necessary for specific types of research, are used less regularly. For example, dangerous biological agents that have the potential to be inhaled during experimental procedures require additional biosafety practices and measures, such as a biological safety cabinet (BSC), one of the most important pieces of laboratory equipment to reduce the risk of inhalational exposure. Unfortunately, BSCs are used by only 64% of researchers who study pathogens that pose an inhalational hazard. The survey did not examine whether BSCs are regularly, or annually, certified. In addition, many of the laboratories that work

Table 6a

Risk perceptions that a respondent's laboratory would be involved in or affected by one of the following scenarios.*

	Discovering Emerging Infectious Disease	Repurposed by Government to Serve as Public Health Lab During Epidemic	Theft of Samples by Laboratory Employee with Intent to Cause Harm	Theft of Samples by Non-employee with Intent to Cause Harm
Basic Research				
Asia (n=103)	3.4	3.5	2.3	2.2
Eastern Europe (n=72)	2.7	2.9	1.8	1.8
Latin America (n=82)	2.9	3.9	1.8	1.8
Middle East (n=57)	3.3	3.6	2.0	2.1
AVERAGE	**3.1**	**3.5**	**2.0**	**2.0**
Clinical Research				
Asia (n=45)	4.3	5.0	2.1	2.0
Eastern Europe (n=24)	3.3	3.8	2.1	2.1
Latin America (n=21)	4.0	4.1	1.9	1.8
Middle East (n=51)	3.9	4.4	2.5	2.3
AVERAGE	**3.9**	**4.3**	**2.2**	**2.1**
Disease Surveillance Research				
Asia (n=49)	4.8	5.1	2.6	2.6
Eastern Europe (n=23)	4.4	5.0	1.8	2.3
Latin America (n=40)	4.2	5.4	1.9	1.5
Middle East (n=26)	4.7	4.8	2.4	1.9
AVERAGE	**4.5**	**5.1**	**2.2**	**2.1**
Drug Discovery Research				
Asia (n=51)	3.5	4.0	2.0	2.0
Eastern Europe (n=19)	2.3	3.3	1.8	1.7
Latin America (n=9)	2.6	3.6	1.2	1.3
Middle East (n=11)	2.8	2.7	2.5	2.1
AVERAGE	**2.8**	**3.4**	**1.9**	**1.8**
Translational Research				
Asia (n=12)	3.6	3.8	2.2	2.0
Eastern Europe (n=3)	2.0	2.3	1.7	1.7
Latin America (n=7)	3.0	4.1	1.0	1.4
Middle East (n=8)	3.5	3.8	1.9	2.6
AVERAGE	**3.0**	**3.5**	**1.7**	**1.9**

*This question was answered on a 7-point scale: 7=very likely; 1=very unlikely. The above scores are an average of the respondents' results.

on some of the most dangerous pathogens do not commonly use controlled access measures (double-door entry, physical isolation of the laboratory), and, moreover, these laboratories do not appear equipped to handle accidents, as the majority of them lack a sealable room for decontamination or an anteroom. Enhanced biosafety measures such as a double-ended autoclave, an anteroom with a shower, and closed-circuit television are rare.

While many respondents appear to be concerned about the natural route of infection or an agent's pathogenicity, the majority of respondents studying dangerous infectious agents do so at one biosafety level lower than that recommended in applicable guidance from the World Health Organization and/or the Centers for Disease Control and Prevention (CDC). In Asia, for example, nearly two-thirds of respondents investigating Japanese encephalitis, avian influenza, and SARS perform their research under BSL-2 conditions.

One explanation for this discrepancy is that some of these labs are diagnosing clinical specimens for which BSL-2 work practices would be appropriate. Another possibility is that respondents' laboratories are not able—due to lack of resources—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. In many cases, the respondents are not aware of their laboratory's official biosafety level or are not entirely clear what the various biosafety levels are or when they are needed. For example, one respondent from Pakistan reported using a BSL-4 when researching food-borne pathogens such as *E. coli* and *S. typhi* in his/her laboratory. Another Pakistani reported using a BSL-4 for research in a basic research laboratory while a respondent from Jordan reported using a BSL-4 for research in a clinical laboratory. Yet, no evidence in the public literature confirms that either of these countries operates a BSL-4 facility. Moreover, further reviews of individual biosafety responses do not support the engineering controls consistent with a BSL-4 laboratory.

Table 6b

Risk perceptions that a respondent's laboratory would be involved in or affected by one of the following scenarios.*

	Discovering Emerging Infectious Disease	Repurposed by Government to Serve as Public Health Lab During Epidemic	Theft of Samples by Laboratory Employee with Intent to Cause Harm	Theft of Samples by Non-employee with Intent to Cause Harm
Food-borne Pathogens				
Asia (n=27)	4.2	4.2	2.4	2.7
Eastern Europe (n=9)	1.7	2.6	1.5	1.5
Latin America (n=12)	2.5	3.5	2.8	3.0
Middle East (n=12)	3.0	4.0	1.7	1.2
AVERAGE	**2.9**	**3.6**	**2.1**	**2.1**
Emerging Pathogens				
Asia (n=6)	4.2	4.2	2.7	2.3
Eastern Europe (n=2)	4.0	4.0	2.0	1.0
Latin America (n=3)	5.0	7.0	1.0	1.0
Middle East (n=1)	1.0	1.0	1.0	1.0
AVERAGE	**3.6**	**4.0**	**1.7**	**1.3**
Blood-borne Pathogens				
Asia (n=14)	3.6	3.6	2.4	2.4
Eastern Europe (n=2)	4.0	3.5	1.0	3.0
Latin America (n=8)	2.9	4.9	1.4	1.3
Middle East (n=1)	4.0	4.0	4.0	4.0
AVERAGE	**3.6**	**4.0**	**2.2**	**2.7**
Pathogens Posing an Inhalational Risk				
Asia (n=5)	3.8	3.6	2.6	2.4
Eastern Europe (n=5)	2.8	2.6	1.6	2.0
Latin America (n=5)	3.0	5.2	2.0	1.6
Middle East (n=7)	3.9	4.7	2.4	2.3
AVERAGE	**3.4**	**4.0**	**2.2**	**2.1**

*This question was answered on a 7-point scale: 7=very likely; 1=very unlikely. The above scores are an average of the respondents' results.

In general, fewer laboratories utilize biosecurity-related measures than biosafety-related measures. An overwhelming majority consider the *Theft of samples with the intent to do harm* by an employee or non-employee highly unlikely. While most respondents' laboratories employ minimal biosecurity measures, the fact that the awareness level and perceived threats about biological terrorism is so low suggests that these measures are likely not implemented to the standards recommended by the WHO. Many of the respondents who are not implementing biosecurity are engaged in research with dangerous endemic agents, such as foot-and-mouth disease virus, dengue fever virus, SARS-CoV, and avian influenza virus. In addition, many of the respondents who do not consider the *Theft of samples with the intent to do harm* by an employee or non-employee a concern also specifically identify a biosafety concern, *Accidently infecting people, animals or the environment*.

Simple Practices and Techniques Predominate

Simple biosafety and biosecurity measures predominate in every survey category, while more sophisticated and expensive measures are used by a significantly smaller proportion of respondents who, in most cases, reside in wealthier countries. As previously mentioned, the most common biosafety practice is the use of personal protective equipment such as gloves, goggles, and gowns. Expensive technologies like two-way communication, positive pressure suits, and pass-through autoclaves are rarely used. Furthermore, most of the sophisticated techniques and equipment are located in the handful of BSL-4 laboratories scattered throughout the survey regions. When asked about the types of laboratory techniques used with infectious agents and/or toxins, the majority of respondents reported using simple tools routinely, for example classical polymerase chain reaction (PCR), enzyme-linked immunosorbent assays (ELISAs), and electrophoresis. Advanced genotyping and gene expression analysis technologies, such as single nucleotide polymorphism (SNP), RNA interference (RNAi), and deoxyribonucleic acid (DNA) microarrays, are used only by a small percentage of respondents.

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. Many of these laboratories simply post a guard at the building entrance and lock their cabinets, building, and laboratory doors; the use of engineered security controls such as intrusion sensors, alarms, and video monitors are rare in developing countries. Personnel-based security measures are inherently less effective; electronic systems are more reliable and have the advantage of providing constant monitoring.

Perceptions of Risk Vary Regionally

In general, the overall perception of risk varied among regions. Latin American and Asian respondents were the most concerned about various scenarios involving an infectious agent or toxin in their laboratories (Tables 5a and 5b). When considering the survey's five types of laboratory risk, Latin Americans respondents were consistently most concerned with *Accidentally infecting people, animals or the environment* and *Laboratory-acquired infections* across all research type categories, except Latin American labs that perform disease surveillance and translational research. Latin American respondents who study drug discovery research were most concerned with each of the survey's proposed laboratory risks; Asian disease surveillance researchers were also concerned with all of the risks (Table 5a).

Similarly, all Asian research laboratories were most concerned with *Discovering an Emerging Infectious Disease* (Table 6a). Being *Repurposed by government to serve as a public health lab during an epidemic* is a concern for Latin American labs researching emerging pathogens, blood-borne pathogens, and pathogens that present an inhalational hazard (Table 6b).

Generally, Middle Eastern respondents who study pathogens that present an inhalational hazard are the most worried about the laboratory risks presented in the survey, while Eastern European researchers of the same category were the least concerned about all the risks (Table 5b). Furthermore, regional analysis of biosafety levels reveals that Middle Eastern respondents consistently do not know at which BSL level they currently work (Table 3a).

It is important to note that when risk perceptions of individual countries in each region were analyzed, no trends could be identified. The responses of participants from various institutions within a region, even within the same country, differed dramatically. For example, in two Indian disease surveillance labs, one categorized the lab scenario risk as extremely high, while another found absolutely no risk. This was common in both wealthy and poor countries. The only discernable trend in the risk perception data was that respondents from the wealthier countries collectively perceive much greater risk than the poor countries, perhaps indicating better awareness.

Conclusions

This work has highlighted the strengths and weaknesses of laboratory biosafety and biosecurity internationally. Survey results revealed that participants are actively engaged in research with a wide variety of biological agents, including *Salmonella typhi*, *Escherichia coli O157:H7*, *Shigella dysenteriae,* HIV, and *Staphylococcus aureus* toxin. *Mycobacterium tuberculosis* is also commonly researched in many countries, while Asia investigates SARS, highly pathogenic avian influenza, and dengue fever much more frequently than any other region. In contrast, biosafety and biosecurity practices around the world are varied. Results of these analyses were summarized into three major trends or themes:

biosafety is more prevalent than biosecurity, simple practices and techniques predominate, and perceptions of risk vary regionally.

One reason why biosecurity is employed less often is because laboratory biosecurity is a relatively new concept, even in U.S. laboratories. In regions which do recognize biosafety within a laboratory framework, biosecurity may not be independently recognized, or it is interpreted to mean the same as biosafety. This susceptibility is likely to be even greater for those laboratories that strongly rely on security provided by humans (e.g., entry guards or security patrols) rather than technology, a trend that is more typical of laboratories located in *Developing/Emerging* countries than in *Advanced* countries.

Respondents cite a variety of reasons for poor research practices. In all regions, respondents claimed a lack of funding and other resources as the primary factor that prevents laboratories from applying appropriate biosafety and biosecurity measures. A lack of funds, especially in the *Developing/Emerging* countries, prohibits laboratories from purchasing the necessary equipment and hiring qualified staff. A lack of awareness or education is also a significant hurdle. Many respondents are guided by their employers or employee training, but biosafety training is minimally conducted in all regions. Furthermore, nearly every region reports looking to its country's government to help shape its biosafety and biosecurity practices in the laboratory. Yet, for many countries, no national regulations or guidance exists.

A lack of a perception of risk also exists. Interestingly, when considering the individual countries that have been affected by SARS or avian influenza, several respondents reported their most significant worry was *Laboratory-acquired infections* and *Increased virulent strains*; however, the majority did not utilize the necessary biosafety precautions to mitigate those risks. It is likely that institutes that lack the appropriate biosafety practices will have frequent laboratory-acquired infections, although no information is available in the open source literature to confirm this. Even so, many respondents' ignorance or dismissal of the possible harm a particular pathogen might cause, in the event of accidental exposure, is worrying.

The authors acknowledge the inherent limitations and shortcomings associated with this survey data, and, therefore, do not recommend that its results be used alone to sufficiently or confidently assess risk or to generate conclusions that could potentially shape policy. Most surveys, including this survey, are seldom truly random since responses are voluntary; participants may be more likely to respond if they feel strongly about a subject, potentially resulting in a bimodal distribution of data. Furthermore, 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.

The points or honoraria given to participants were designed to counterbalance this possibility, perhaps by motivating those less likely to be responsive. However, approaches such as these may result in a situation where financially poor institutions respond more frequently, thereby artificially overestimating regional risk and under-representing comparatively well-funded institutions that may have better risk-reducing practices and equipment in place. Moreover, certain groups or subgroups may simply be over-represented in the participant pool or be more likely to respond to a survey for cultural reasons. For example, Indian scientists responded most frequently to the Asia survey; thus, India is represented to a greater degree relative to other countries. Also apparent is that, for many survey questions, data stratification greatly reduced the sample size, thereby limiting the statistical power of the study. In addition, this survey targets just four regions of the world; therefore, generalizing these data to other regions of the world may or may not be appropriate. Similar surveys are planned in the future for Africa, North America, and Western Europe.

Lastly, although laboratory policies and procedures are critical for the successful implementation of biosafety and biosecurity, these are harder to measure objectively in a survey format; therefore, this survey focused predominately on whether laboratories had specific items in place to address biosafety and biosecurity (e.g., the existence of written documentation, locks on doors, badges, biosafety cabinets, etc.). This is a fundamental limitation of the way this survey was designed since many laboratories around the world successfully handle dangerous pathogens without staff acquiring infections by implementing strong procedural controls and training instead of relying on engineered controls. Therefore, this survey structure should not be interpreted as a recommendation for engineered controls over procedural controls.

Nonetheless, given a thorough consideration of the potential caveats associated with survey analyses, surveys are an important tool for collecting data necessary to make firmer, more informed risk assessments of broad, often intractable problems, and, therefore, the authors believe this survey provides many valuable insights. To date, surveys of biosafety and biosecurity practices are rare and relatively narrow in scope. This survey is exceptional in that it presents a summary of data from various types of countries in four different regions of the world.

In addition, these findings are supported by previously published incidents and evidence of negligent biosafety and biosecurity practices, domestically and internationally. In Europe, an onsite audit of 22 facilities, including 94 Danish laboratories, found poor biosecurity widely prevalent, with open access to freezers containing lethal viruses and bacteria, such as *Bacillus anthracis*, foot-and-mouth disease virus, and *Yersinia pestis*; 90%

of the laboratories studied did not conduct regular inventory checks or perform personnel background checks (Bork et al., 2007). Similarly, in 2006, Texas A&M was cited for a variety of biosecurity problems, ranging from unauthorized access to high-security labs, missing vials of infectious agents including *Brucella* bacteria, improper disposal of infected animals, negligence in using personal protective equipment, and failure to report exposure of laboratory workers, to dangerous biological agents (Kaiser, 2007; Ramshaw, 2007). Other recent high-profile biosafety breaches include the laboratory-acquired infections of SARS in 2003 and 2004, and the accidental release of foot-and-mouth disease virus from a laboratory in the United Kingdom in 2007 (Health and Safety Executive, 2007; Taylor et al., 2005).

This survey shows that much work remains to be done internationally to safely and securely manage infectious agents and toxins and to reduce the risk of exposure and theft. Establishing a culture of safety, security, and responsibility will be immensely challenging, especially in those areas of the world that do not perceive the risks and/or lack adequate resources to mitigate those risks. So that the United States can contribute more effectively to the ongoing efforts to promote biosafety and biosecurity, more information needs to be collected about laboratory policies and practices worldwide. When combined with insights obtained through complementary and collaborative relationships with partners in this field, this wealth of data can be used to better raise global awareness of the critical issues involved with developing, implementing, and overseeing biosafety and biosecurity measures in bioscience institutes around the world.

References

Bork, K. H., Halkjaer-Knudsen, V., Hansen, J. E., & Heegaard, E. D. (2007). Biosecurity in Scandinavia. *Biosecurity and Bioterrorism, 5,* 62-71.

Health and Safety Executive. (2007). *Final report on potential breaches to biosecurity at the Pirbright site.* Available at: www.hse.gov.uk/news/archive/07aug/footandmouth.htm. Accessed online 2009.

Kaiser, J. (2007). Pathogen work at Texas A&M suspended. *ScienceNOW Daily News.* Available at: http://sciencenow.sciencemag.org/cgi/content/full/2007/702/1. Accessed online 2009.

MSNBC (2007). *US labs mishandling deadly germs*. Available at: www.msnbc.msn.com/id/21096974/. Accessed online 2009.

Public Health Security and Bioterrorism Preparedness and Response Act of 2002, Public Law 107-188 June 12, 2002. Available at: www.fda.gov/RegulatoryInformation/Legislation/ucm155733.htm

Ramshaw, E. (2007). CDC reprimands Texas A&M over lab safety. *Dallas Morning News*. Available at: www.dallasnews.com/sharedcontent/dws/news/healthscience/stories/090507dntexcdc.9f66c8cc.html. Accessed online 2009.

Salerno, R. M., & Gaudioso, J. M. (2007). *Laboratory biosecurity handbook*, (pp. 42, 48). Boca Raton, FL: CRC Press.

Sandia National Laboratories, International Biological Threat Reduction. *SAND Report 2009-0868*. Available at: www.biosecurity.sandia.gov

Taylor, J., Wentworth, D. E., Bernard, K. A., Masters, P. S., & Trimarchi, C. V. (2005). SARS coronaviruses and highly pathogenic influenza viruses: Safety and occupational health for laboratory workers (conference summary). *Emerging Infectious Diseases,* Available at: www.cdc.gov/ncidod/EID/vol11no04/04-1304.htm. Accessed online 2009.

Uniting and Strengthening America by Providing Appropriate Tools Required to Intercept and Obstruct Terrorism (USA PATRIOT Act), Public Law 107-54 October 26, 2001. Available at: https://www.biosecurity.sandia.gov/legislation

U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC), and National Institutes of Health (NIH). (2007). *Biosafety in microbiological and biomedical laboratories* (5th ed.). Washington, DC: U.S. Government Printing Office. Available at: www.cdc.gov/od/ohs/biosfty/bmbl5/bmbl5toc.htm

World Health Organization (WHO). (2004). *Laboratory biosafety manual*. Available at: www.who.int/csr/resources/publications/biosafety/Biosafety7.pdf. Accessed online 2009.

The Transfederal Taskforce on Biosafety and Biocontainment Oversight Report

The purpose of the Task Force is to propose options and recommendations to improve biosafety and biocontainment oversight of research and research-related activities at high and maximum containment laboratories in the United States, without hindering the progress of science. The scope of activities considered by the Task Force includes those that occur in all high and maximum containment research laboratories in all sectors (government [Federal, State, Tribal, and municipal], academia, privately funded research institutions, and private industry) utilizing potentially hazardous biological agents. The activities covered include research with disease-causing agents (pathogens) that can infect humans, zoonotic agents that can infect both animals and humans, biologic toxins, and agricultural pathogens and pests. Also included are activities related to research, such as the maintenance of facilities and equipment needed for effective biosafety and biocontainment, incident-reporting, and public outreach and communication efforts. Available at: www.hhs.gov/aspr/omsph/biosafetytaskforce/index.html