

## Comparative Analysis of the Fourth and Fifth Editions of *Biosafety in Microbiological and Biomedical Laboratories* Section IV (BSL2-4)

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### Abstract

*We developed a matrix of changes between Section IV of the current and former editions of Biosafety in Microbiological and Biomedical Laboratories (BMBL), focusing on biosafety levels two, three, and four (BSL2, BSL3, and BSL4). Citations containing multiple statements were subdivided into individually addressable statements and statements with similar/identical scope were aligned, allowing for a precise comparative analysis. In addition, statements were categorized for further analysis based on the subject of the change, the type of change, and the outcome of the change. Although the Fifth Edition of BMBL (BMBL5) proved to be a close facsimile of its predecessor, we identified 375 total changes, including 165 novel statements not addressed in the former edition. Over 65% (110) of these changes were found in statements pertaining to BSL4 containment. In our study, we further examine these edition differences and identify key areas where those entities responsible for compliance with these new recommendations may wish to focus their efforts.*

### Introduction

First introduced in 1984, BMBL is an advisory document recommending best practices for the safe conduct of work in biomedical and clinical laboratories. Since its inception, it has become one of the most frequently used codes of practice in biosafety, and an authoritative reference for: the development of laboratory policies and procedures, the construction of new laboratories, and the renovation of existing laboratories (U.S. Department of Health and Human Services, 1999). Over the past two decades, periodic updates have been made to the BMBL to “refine guidance based on new knowledge and experiences and to address contemporary issues that present new risks that confront laboratory workers and the public health” (U.S. Department of Health and Human Services, 2007). In February 2007, a consortium of individuals from the Centers for Disease Control and Prevention (CDC) and National Institutes of Health (NIH) released the fifth edition of the BMBL, which contained a number

of revisions and additions from the former, including:

- Added guidance on laboratory biosecurity and risk assessment.
- Added guidance on agricultural Biosafety Level 3 (BSL3-Ag) laboratories.
- Revisions and additions to agent summary statements.
- Expanded guidance on a number of topics, including decontamination, sterilization, occupational medicine, and immunization.

We report here the development of a change matrix identifying content changes to Section IV (Laboratory Biosafety Level Criteria) between the Fourth Edition of BMBL (BMBL4) and BMBL5, focusing specifically on BSL2-4.

### Methods

The Laboratory Biosafety Level Criteria sections from BMBL4 and BMBL5 were analyzed and a matrix of changes was developed for BSL2-BSL4. The PDF version of BMBL5, released in November 2007 and available at [www.cdc.gov/od/ohs/biosfty/bmb15/BMBL\\_5th\\_Edition.pdf](http://www.cdc.gov/od/ohs/biosfty/bmb15/BMBL_5th_Edition.pdf), was used for this analysis. Both sections were transferred electronically to a Microsoft Excel spreadsheet and separated by citation. Citations containing multiple statements were further subdivided into individually addressable statements to facilitate a detailed comparative analysis independent of simple structural and format differences not affecting meaning. BMBL4 statements were then reorganized and horizontally aligned with BMBL5 statements having a similar or identical scope. The original BMBL4 citations were preserved for cross-referencing. Each statement, or statement pair, was then systematically categorized based on subject, change type, and outcome, for further analysis.

Based upon observed trends in BMBL topics and laboratory commonalities, the following 17 biosafety-related subjects were determined and then assigned to each statement, or statement pair:

- Access
- Biological Safety Cabinet (BSC) design
- BSC exhaust
- BSC usage
- Decontamination

- Doors/Windows
  - Exposures (lab-related accidents/illnesses)
  - Immunization/Serum Collection
  - Laboratory construction
  - Laboratory furnishings (seating, furniture, carpeting)
  - Laboratory ventilation (filtration, vacuums)
  - Miscellaneous (food, cosmetics, pest control)
  - Personal Protective Equipment (PPE)
  - Sharps (glassware, needles, syringes)
  - Signage
  - Sinks/Eyewashes/Fountains
  - Techniques (pipetting, animal use, storage, transfer)
  - Training/Policies/Standardized Operating Procedures
- Six change types, defined below, were then assigned

to the data:

- No change—the statement scopes are identical; any rewording or reorganization does not affect meaning or potential interpretation.
- Not currently addressed—the BMBL4 statement is not addressed in BMBL5.
- Not previously addressed—the BMBL5 statement was not addressed in BMBL4.
- Rewording—the statement scopes are similar; however, the change affects meaning or potential interpretation.
- Scope expansion—the statement scopes are similar; however, the BMBL5 statement has been further expanded to include additional details.
- Scope generalization—the statement scopes are similar; however, the BMBL5 statement has been further generalized to be more all-encompassing.

Finally, three change outcomes were assigned to the data: those requiring only a change in documentation (such as recommendations for the establishment of written manuals), those requiring a change in practice (such as guidance on infectious waste decontamination procedures), and those requiring a facility change (such as guidance on laboratory ventilation requirements). The change matrix tool uses a basic Microsoft Excel filter function to allow users to sort the data based on the aforementioned categorizations as well as by BSL. We are providing the change matrix tool electronically to interested individuals free of charge upon request. In addition, a brief summary of major changes is presented herein.

## Results

An excerpt of the change matrix covering the BSL2 subsection only is shown in Figure 1. For a complete change matrix covering BSL2-4, please contact the author via e-mail at [c crews@constellagroup.com](mailto:c crews@constellagroup.com) or visit the ABSA web site at [www.absa.org/word/BMBLChangeMatrix.xls](http://www.absa.org/word/BMBLChangeMatrix.xls) where the change matrix tool has been posted. This file allows the user to filter and sort the various BMBL statements based on the criteria relevant to a particular laboratory situation. Five hundred twelve total

statement/statement pairs were identified following the subdivision of citations and realignment of BMBL4 statements with similar/identical scope. Of this total, 375 unique changes were identified. Fifty-six percent (211) of these changes were identified as BSL4 statements whereas 26% (97) were identified as BSL3 changes and 18% (67) were identified as BSL2 changes. These results are summarized in Figure 2.

Forty-five percent (166) of the total changes were identified as being unique to BMBL5 (not addressed in the previous edition); 66% of the changes unique to BMBL5 (110) were identified as BSL4 statements; 15% (56) of the total changes were identified as being unique to BMBL4 (not addressed in the current edition); 16% (61) of the total changes were identified as scope generalizations, and 13% (50) were identified as scope expansions. Twelve percent (44) of the total changes were identified as rewordings affecting the statement's meaning. Figure 3 is a summary of the percent of total changes by type.

Figure 4 summarizes the number of changes by subject. The three most frequent subjects for change are decontamination (62, 17%), laboratory ventilation (47, 13%), and personal protective equipment (PPE) (58, 16%). Other notable areas of change include biological safety cabinet (BSC) exhaust (26, 7%), laboratory construction/layout (35, 9%), sharps (25, 7%), and training/standard operating procedures (25, 7%).

Forty-seven percent (177) of the total number of changes between the two BMBL editions are practice changes, whereas 37% (140) are facility changes and 16% (58) are documentation changes. Seventy-one percent (99) of facility changes and 54% (95) of practice changes were identified at BSL4 changes. These data are summarized in Figure 5.

Figure 6 shows a concise summary of the major changes between the fourth and fifth editions of BMBL Section IV. The biosafety levels pertinent to each change, as well as to all applicable BMBL citations are documented. The summary focuses on major practice and facility changes that we have subjectively determined to have a high impact based upon a number of criteria, including: the immediacy of the safety concern, the level of resources required to comply with the change, and the severity of the consequences of non-compliance. The summary is intended to be a quick resource to assist biosafety professionals in concentrating their efforts on specific areas, and is not intended to be definitive or official reference material.

## Discussion

Although the BMBL is not intended as a regulatory document, in some circumstances, compliance with the BMBL has been legally mandated. For biosafety professionals tasked with ensuring facility compliance with the BMBL, keeping abreast of changing guidance poses a

**Figure 1**

A change matrix comparing 4th and 5th editions of *Biosafety in Microbiological and Biomedical Laboratories*, Section IV. This figure only presents BSL2 changes. For a complete change matrix covering BSL2-4, please contact the author via e-mail at [ccews@constellagroup.com](mailto:ccews@constellagroup.com) or visit the ABSA web site at [www.absa.org/word/BMBLChangeMatrix.xls](http://www.absa.org/word/BMBLChangeMatrix.xls) where the change matrix tool has been posted.

Item #	BSL	Subject	BMBL-4 Section	BMBL-4	BMBL-5 Section	BMBL-5 (PDF version)	Change Type	Outcome
<b>Biosafety Level 2</b>								
<b>A. Standard Microbiological Practices</b>								
1	BSL2	Access	BMBL4: A1	Access to the laboratory is limited or restricted at the discretion of the laboratory director when experiments are in progress.	BMBL5: A1	The laboratory supervisor must enforce the institutional policies that control access to the laboratory.	Rewording	PC
2	BSL2	Decon.	BMBL4: A2	Persons wash their hands after they handle viable materials, after removing gloves, and before leaving the laboratory.	BMBL5: A2	Persons must wash their hands after working with potentially hazardous materials and before leaving the laboratory.	Rewording	PC
3	BSL2	Misc.	BMBL4: A3	Eating, drinking, smoking, handling contact lenses, and applying cosmetics are not permitted in the work areas.	BMBL5: A3	Eating, drinking, smoking, handling contact lenses, applying cosmetics, and storing food for human consumption must not be permitted in laboratory areas.	Expansion	DC
4	BSL2	Misc.	BMBL4: A3	Food is stored outside the work area in cabinets or refrigerators designated for this purpose only.	BMBL5: A3	Food must be stored outside the laboratory area in cabinets or refrigerators designated and used for this purpose.	No Change	NC
5	BSL2	Techniques	BMBL4: A4	Mouth pipetting is prohibited;	BMBL5: A4	Mouth pipetting is prohibited;	No Change	NC
6	BSL2	Techniques	BMBL4: A4	mechanical pipetting devices are used.	BMBL5: A4	mechanical pipetting devices must be used.	No Change	NC
7	BSL2	Sharps	BMBL4: A5	Policies for the safe handling of sharps are instituted.	BMBL5: A5	Policies for the safe handling of sharps, such as needles, scalpels, pipettes, and broken glassw are must be developed and implemented.	Expansion	DC
8	BSL2	Sharps			BMBL5: A5	Whenever practical, laboratory supervisors should adopt improved engineering and work practice controls that reduce risk of sharps injuries.	NPA	DC
9	BSL2	Sharps	BMBL4: B8	A high degree of precaution must always be taken with any contaminated sharp items, including needles and syringes, slides, pipettes, capillary tubes, and scalpels.	BMBL5: A5	Precautions, including those listed below, must always be taken with sharp items. These include:	No Change	NC
10	BSL2	Sharps	BMBL4: B8-a	Needles and syringes or other sharp instruments should be restricted in the laboratory for use only when there is no alternative, such as parenteral injection, phlebotomy, or aspiration of fluids from laboratory animals and diaphragm bottles.			NCA	DC
11	BSL2	Sharps	BMBL4: B8-b	Only needle-locking syringes or disposable syringe-needle units (i.e., needle is integral to the syringe) are used for injection or aspiration of infectious materials.			NCA	DC
12	BSL2	Sharps			BMBL5: A5-a	Careful management of needles and other sharps are of primary importance.	NPA	DC
13	BSL2	Sharps	BMBL4: B8-b	Used disposable needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal	BMBL5: A5-a	Needles must not be bent, sheared, broken, recapped, removed from disposable syringes, or otherwise manipulated by hand before disposal.	Generalization	PC
14	BSL2	Sharps	BMBL4: B8-b	rather, they must be carefully placed in conveniently located puncture-resistant containers used for sharps disposal.	BMBL5: A5-b	Used disposable needles and syringes must be carefully placed in conveniently located puncture-resistant containers used for sharps disposal.	No Change	NC
15	BSL2	Sharps	BMBL4: B8-b	Non-disposable sharps must be placed in a hard-walled container for transport to a processing area for decontamination, preferably by autoclaving.	BMBL5: A5-c	Non-disposable sharps must be placed in a hard-walled container for transport to a processing area for decontamination, preferably by autoclaving.	No Change	NC
16	BSL2	Sharps	BMBL4: B8-c	Syringes which re-sheath the needle, needleless systems, and other safety devices are used when appropriate.			NCA	DC
17	BSL2	Sharps	BMBL4: B8-d	Broken glassw are must not be handled directly by hand, but must be removed by mechanical means such as a brush and dustpan, tongs, or forceps.	BMBL5: A5-d	Broken glassw are must not be handled directly. Instead, it must be removed using a brush and dustpan, tongs, or forceps.	No Change	NC
18	BSL2	Sharps	BMBL4: B8-d	Containers of contaminated needles, sharp equipment, and broken glass are decontaminated before disposal, according to any local, state, or federal regulations			NCA	DC
19	BSL2	Sharps	BMBL4: B8-a	Plasticw are should be substituted for glassw are whenever possible.	BMBL5: A5-d	Plasticw are should be substituted for glassw are whenever possible.	No Change	NC
20	BSL2	Techniques	BMBL4: A6	All procedures are performed carefully to minimize the creation of splashes or aerosols.	BMBL5: A6	Perform all procedures to minimize the creation of splashes and/or aerosols.	No Change	NC
21	BSL2	Decon.	BMBL4: A7	Work surfaces are decontaminated on completion of work or at the end of the day and after any spill or splash of viable material with disinfectants that are effective against the agents of concern.	BMBL5: A7	Decontaminate work surfaces after completion of work and after any spill or splash of potentially infectious material with appropriate disinfectant.	No Change	NC
22	BSL2	Decon.	BMBL4: A8	All cultures, stocks, and other regulated wastes are decontaminated before disposal by an approved decontamination method such as autoclaving.	BMBL5: A8	Decontaminate all cultures, stocks, and other potentially infectious materials before disposal using an effective method.	Rewording	PC
23	BSL2	Decon.			BMBL5: A8	Depending on where the decontamination will be performed, the following methods should be used prior to transport:	No Change	NC
24	BSL2	Decon.	BMBL4: A8	Materials to be decontaminated outside of the immediate laboratory are placed in a durable, leakproof container and closed for transport from the laboratory.	BMBL5: A8-a	Materials to be decontaminated outside of the immediate laboratory must be placed in a durable, leak proof container and secured for transport.	No Change	NC
25	BSL2	Decon.	BMBL4: A8	Materials to be decontaminated off-site from the facility are packaged in accordance with applicable local, state, and federal regulations before removal from the facility.	BMBL5: A8-b	Materials to be removed from the facility for decontamination must be packed in accordance with applicable local, state, and federal regulations.	No Change	NC

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Figure 1 (Con't.)

Item #	BSL	Subject	BMBL-4 Section	BMBL-4	BMBL-5 Section	BMBL-5 (PDF version)	Change Type	Outcome
26	BSL2	Signage	BMBL4: B3	A biohazard sign must be posted on the entrance to the laboratory when etiologic agents are in use.	BMBL5: A9	A sign incorporating the universal biohazard symbol must be posted at the entrance to the laboratory when infectious agents are present.	Rewording	FC
27	BSL2	Signage	BMBL4: B3	Appropriate information to be posted includes the agent(s) in use, the biosafety level, the required immunizations, the investigator's name and telephone number, any personal protective equipment that must be worn in the laboratory, and any procedures required for exiting the laboratory.	BMBL5: A9	Posted information must include: the laboratory's biosafety level, the supervisor's name (or other responsible personnel), telephone number, and required procedures for entering and exiting the laboratory.	Generalization	DC
28	BSL2	Signage	BMBL4: B3	Appropriate information to be posted includes the agent(s) in use	BMBL5: A9	Agent information should be posted in accordance with the institutional policy.	Rewording	FC
29	BSL2	Misc.	BMBL4: A9	An insect and rodent control program is in effect.	BMBL5: A10	An effective integrated pest management program is required. See Appendix G.	Expansion	PC
30	BSL2	Training/SOPs	BMBL4: B7	The laboratory director ensures that laboratory and support personnel receive appropriate training on the potential hazards associated with the work involved, the necessary precautions to prevent exposures, and the exposure evaluation procedures.	BMBL5: A11	The laboratory supervisor must ensure that laboratory personnel receive appropriate training regarding their duties, the necessary precautions to prevent exposures, and exposure evaluation procedures.	Rewording	PC
31	BSL2	Training/SOPs	BMBL4: B7	Personnel receive annual updates or additional training as necessary for procedural or policy changes.	BMBL5: A11	Personnel must receive annual updates or additional training when procedural or policy changes occur.	No Change	NC
32	BSL2	Training/SOPs			BMBL5: A11	Personal health status may impact an individual's susceptibility to infection, ability to receive immunizations or prophylactic interventions. Therefore, all laboratory personnel and particularly women of child-bearing age should be provided with information regarding immune competence and conditions that may predispose them to infection.	NPA	PC
33	BSL2	Training/SOPs			BMBL5: A11	Individuals having these conditions should be encouraged to self-identify to the institution's healthcare provider for appropriate counseling and guidance.	NPA	PC
<b>B. Special Practices</b>								
34	BSL2	Access	BMBL4: B1	Access to the laboratory is limited or restricted by the laboratory director when work with infectious agents is in progress. In general, persons who are at increased risk of acquiring infection, or for whom infection may have serious consequences, are not allowed in the laboratory or animal rooms. For example, persons who are immunocompromised or immunosuppressed may be at increased risk of acquiring infections. The laboratory director has the final responsibility for assessing each circumstance and determining who may enter or work in the laboratory or animal room.			NCA	PC
35	BSL2	Access	BMBL4: B2	The laboratory director establishes policies and procedures whereby only persons who have been advised of the potential hazards and meet specific entry requirements (e.g., immunization) may enter the laboratory.	BMBL5: B1	All persons entering the laboratory must be advised of the potential hazards and meet specific entry/exit requirements.	Generalization	PC
36	BSL2	Immunization/ Serum Collection	BMBL4: B4	Laboratory personnel receive appropriate immunizations or tests for the agents handled or potentially present in the laboratory (e.g., hepatitis B vaccine or TB skin testing).	BMBL5: B2	Laboratory personnel must be provided medical surveillance and offered appropriate immunizations for agents handled or potentially present in the laboratory.	Expansion	PC
37	BSL2	Immunization/ Serum Collection	BMBL4: B5	When appropriate, considering the agent(s) handled, baseline serum samples for laboratory and other at-risk personnel are collected and stored. Additional serum specimens may be collected periodically, depending on the agents handled or the function of the facility.	BMBL5: B3	Each institution must establish policies and procedures describing the collection and storage of serum samples from at-risk personnel.	Generalization	DC
38	BSL2	Training/SOPs	BMBL4: B6	Biosafety procedures are incorporated into standard operating procedures or in a biosafety manual adopted or prepared specifically for the laboratory by the laboratory director.	BMBL5: B4	A laboratory-specific biosafety manual must be prepared and adopted as policy.	Generalization	DC
39	BSL2	Training/SOPs	BMBL4: B6	Personnel are advised of special hazards and are required to read and follow instructions on practices and procedures.			NCA	DC
40	BSL2	Training/SOPs			BMBL5: B4	The biosafety manual must be available and accessible.	NPA	PC
41	BSL2	Training/SOPs			BMBL5: B5	The laboratory supervisor must ensure that laboratory personnel demonstrate proficiency in standard and special microbiological practices before working with BSL-2 agents.	NPA	PC
42	BSL2	Techniques	BMBL4: B9	Cultures, tissues, specimens of body fluids, or potentially infectious wastes are placed in a container with a cover that prevents leakage during collection, handling, processing, storage, transport, or shipping.	BMBL5: B6	Potentially infectious materials must be placed in a durable, leak proof container during collection, handling, processing, storage, or transport within a facility.	Generalization	PC
43	BSL2	Decon.	BMBL4: B10	Laboratory equipment and work surfaces should be decontaminated with an effective disinfectant on a routine basis, after work with infectious materials is finished, and especially after overt spills, splashes, or other contamination by infectious materials.	BMBL5: B7	Laboratory equipment should be routinely decontaminated, as well as, after spills, splashes, or other potential contamination.	Generalization	PC

NPA = Not Previously Addressed; NCA = Not Currently Addressed; DC = Documentation Change; FC = Facility Change; PC = Policy/Procedural Change; NC = No Change

Figure 1 (Con't.)

Item #	BSL	Subject	BMBL-4 Section	BMBL-4	BMBL-5 Section	BMBL-5 (PDF version)	Change Type	Outcome
44	BSL2	Decon.			BMBL5: B7-a	Spills involving infectious materials must be contained, decontaminated, and cleaned up by staff properly trained and equipped to work with infectious material.	NPA	PC
45	BSL2	Decon.	BMBL4: B10	Contaminated equipment must be decontaminated according to any local, state, or federal regulations before it is sent for repair or maintenance or packaged for transport in accordance with applicable local, state, or federal regulations, before removal from the facility.	BMBL5: B7-b	Equipment must be decontaminated before repair, maintenance, or removal from the laboratory.	Generalization	PC
46	BSL2	Exposures			BMBL5: B8	Incidents that may result in exposure to infectious materials must be immediately evaluated and treated according to procedures described in the laboratory biosafety safety manual.	NPA	PC
47	BSL2	Exposures	BMBL4: B11	Spills and accidents that result in overt exposures to infectious materials are immediately reported to the laboratory director.	BMBL5: B8	All such incidents must be reported to the laboratory supervisor.	No Change	NC
48	BSL2	Exposures	BMBL4: B11	Medical evaluation, surveillance, and treatment are provided as appropriate and written records are maintained.	BMBL5: B8	Medical evaluation, surveillance, and treatment should be provided and appropriate records maintained.	No Change	NC
49	BSL2	Techniques	BMBL4: B12	Animals not involved in the work being performed are not permitted in the laboratory.	BMBL5: B9	Animals and plants not associated with the work being performed must not be permitted in the laboratory.	No Change	NC
50	BSL2	Techniques			BMBL5: B10	All procedures involving the manipulation of infectious materials that may generate an aerosol should be conducted within a BSC or other physical containment devices.	NPA	PC
<b>C. Safety Equipment (Primary Barriers and Personal Protective Equipment)</b>								
51	BSL2	BSC usage	BMBL4: C1	Properly maintained biological safety cabinets, preferably Class II, or other appropriate personal protective equipment or physical containment devices are used whenever:	BMBL5: C1	Properly maintained BSCs (preferably Class II), other appropriate personal protective equipment, or other physical containment devices must be used whenever:	No Change	NC
52	BSL2	BSC usage	BMBL4: C1-a	Procedures with a potential for creating infectious aerosols or splashes are conducted. These may include centrifuging, grinding, blending, vigorous shaking or mixing, sonic disruption, opening containers of infectious materials whose internal pressures may be different from ambient pressures, inoculating animals intranasally, and harvesting infected tissues from animals or embryonate eggs.	BMBL5: C1-a	Procedures with a potential for creating infectious aerosols or splashes are conducted. These may include pipetting, centrifuging, grinding, blending, shaking, mixing, sonicating, opening containers of infectious materials, inoculating animals intranasally, and harvesting infected tissues from animals or eggs.	Expansion	PC
53	BSL2	BSC usage	BMBL4: C1-b	High concentrations or large volumes of infectious agents are used. Such materials may be centrifuged in the open laboratory if sealed rotor heads or centrifuge safety cups are used, and if these rotors or safety cups are opened only in a biological safety cabinet.	BMBL5: C1-b	High concentrations or large volumes of infectious agents are used. Such materials may be centrifuged in the open laboratory using sealed rotor heads or centrifuge safety cups.	Generalization	PC
54	BSL2	PPE	BMBL4: C3	Protective laboratory coats, gowns, smocks, or uniforms designated for lab use are worn while in the laboratory.	BMBL5: C2	Protective laboratory coats, gowns, smocks, or uniforms designated for laboratory use must be worn while working with hazardous materials.	Expansion	PC
55	BSL2	PPE	BMBL4: C3	This protective clothing is removed and left in the laboratory before leaving for non-laboratory areas (e.g., cafeteria, library, administrative offices).	BMBL5: C2	Remove protective clothing before leaving for non-laboratory areas (e.g., cafeteria, library, administrative offices).	No Change	NC
56	BSL2	PPE	BMBL4: C3	All protective clothing is either disposed of in the laboratory or laundered by the institution; it should never be taken home by personnel.	BMBL5: C2	Dispose of protective clothing appropriately, or deposit it for laundering by the institution.	No Change	NC
57	BSL2	PPE	BMBL4: C3		BMBL5: C2	It is recommended that laboratory clothing not be taken home.	Rewording	PC
58	BSL2	PPE	BMBL4: C2	Face protection (goggles, mask, face shield or other splatter guard) is used for anticipated splashes or sprays of infectious or other hazardous materials to the face when the microorganisms must be manipulated outside the BSC.	BMBL5: C3	Eye and face protection (goggles, mask, face shield or other splatter guard) is used for anticipated splashes or sprays of infectious or other hazardous materials when the microorganisms must be handled outside the BSC or containment device.	Expansion	PC
59	BSL2	PPE			BMBL5: C3	Eye and face protection must be disposed of with other contaminated laboratory waste or decontaminated before reuse.	NPA	PC
60	BSL2	Misc.	BMBL4: A3	Persons who wear contact lenses in laboratories should also wear goggles or a face shield.	BMBL5: C3	Persons who wear contact lenses in laboratories should also wear eye protection.	Generalization	PC
61	BSL2	PPE	BMBL4: C4	Gloves are worn when hands may contact potentially infectious materials, contaminated surfaces or equipment.	BMBL5: C4	Gloves must be worn to protect hands from exposure to hazardous materials.	Generalization	PC
62	BSL2	PPE			BMBL5: C4	Glove selection should be based on an appropriate risk assessment.	NPA	PC
63	BSL2	PPE	BMBL4: C4	Alternatives to powdered latex gloves should be available.	BMBL5: C4	Alternatives to latex gloves should be available.	Generalization	FC
64	BSL2	PPE	BMBL4: C4	and they should not be worn outside the lab.	BMBL5: C4	Gloves must not be worn outside the laboratory.	No Change	NC
65	BSL2	PPE			BMBL5: C4	In addition, BSL-2 laboratory workers should:	Generalization	PC
66	BSL2	PPE	BMBL4: C4	Gloves are disposed of when overtly contaminated, and removed when work with infectious materials is completed or when the integrity of the glove is compromised.	BMBL5: C4-a	Change gloves when contaminated, integrity has been compromised, or when otherwise necessary.	Generalization	PC
67	BSL2	PPE	BMBL4: C4	Wearing two pairs of gloves may be appropriate.	BMBL5: C4-a	Wear two pairs of gloves when appropriate.	No Change	NC

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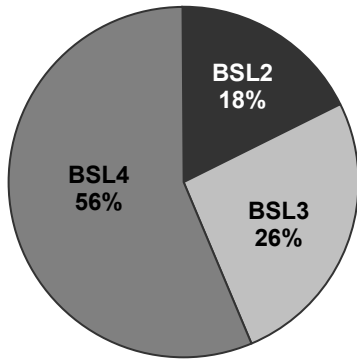
Figure 1 (Con't.)

Item #	BSL	Subject	BMBL-4 Section	BMBL-4	BMBL-5 Section	BMBL-5 (PDF version)	Change Type	Outcome
68	BSL2	PPE	BMBL4: C4	Hands are washed following removal of gloves.	BMBL5: C4-b	Remove gloves and wash hands when work with hazardous materials has been completed and before leaving the laboratory.	Expansion	PC
69	BSL2	PPE	BMBL4: C4	Disposable gloves are not washed, reused, or used for touching "clean" surfaces (keyboards, telephones, etc.).	BMBL5: C4-c	Do not wash or reuse disposable gloves.	Rewording	PC
70	BSL2	PPE			BMBL5: C4-c	Dispose of used gloves with other contaminated laboratory waste.	NPA	PC
71	BSL2	PPE	BMBL4: C4	Hands are washed following removal of gloves.	BMBL5: C4-c	Hand washing protocols must be rigorously followed.	Generalization	PC
72	BSL2	PPE			BMBL5: C5	Eye, face and respiratory protection should be used in rooms containing infected animals as determined by the risk assessment.	NPA	PC
<b>D. Laboratory Facilities (Secondary Barriers)</b>								
73	BSL2	Doors/Windows	BMBL4: D1	Provide lockable doors for facilities that house restricted agents.	BMBL5: D1	Laboratory doors should be self-closing and have locks in accordance with the institutional policies.	Expansion	FC
74	BSL2	Lab Construction	BMBL4: D2	Consider locating new laboratories away from public areas.			NCA	DC
75	BSL2	Sinks/Eyewash	BMBL4: D3	Each laboratory contains a sink for hand washing.	BMBL5: D2	Laboratories must have a sink for hand washing.	No Change	NC
76	BSL2	Sinks/Eyewash			BMBL5: D2	The sink may be manually, hands-free, or automatically operated.	NPA	FC
77	BSL2	Sinks/Eyewash			BMBL5: D2	It should be located near the exit door.	NPA	FC
78	BSL2	Lab Construction	BMBL4: D4	The laboratory is designed so that it can be easily cleaned.	BMBL5: D3	The laboratory should be designed so that it can be easily cleaned and decontaminated.	Expansion	PC
79	BSL2	Lab Furnishings	BMBL4: D4	Carpets and rugs in laboratories are inappropriate.	BMBL5: D3	Carpets and rugs in laboratories are not permitted.	Rewording	FC
80	BSL2	Lab Furnishings	BMBL4: D6	Laboratory furniture is capable of supporting anticipated loading and uses.	BMBL5: D4	Laboratory furniture must be capable of supporting anticipated loads and uses.	No Change	NC
81	BSL2	Lab Construction	BMBL4: D6	Spaces between benches, cabinets, and equipment are accessible for cleaning.	BMBL5: D4	Spaces between benches, cabinets, and equipment should be accessible for cleaning.	No Change	NC
82	BSL2	Lab Construction	BMBL4: D6	Bench tops are impervious to water and are resistant to moderate heat and the organic solvents, acids, alkalis, and chemicals used to decontaminate the work surfaces and equipment.	BMBL5: D4-a	Bench tops must be impervious to water and resistant to heat, organic solvents, acids, alkalis, and other chemicals.	No Change	NC
83	BSL2	Lab Furnishings	BMBL4: D6	Chairs and other furniture used in laboratory work should be covered with a non-fabric material that can be easily decontaminated.	BMBL5: D4-b	Chairs used in laboratory work must be covered with a non-porous material that can be easily cleaned and decontaminated with appropriate disinfectant.	Rewording	FC
84	BSL2	Doors/Windows			BMBL5: D5	Laboratory windows that open to the exterior are not recommended.	NPA	FC
85	BSL2	Doors/Windows	BMBL4: D10	If the laboratory has windows that open to the exterior, they are fitted with fly screens.	BMBL5: D5	However, if a laboratory does have windows that open to the exterior, they must be fitted with screens.	No Change	NC
86	BSL2	BSC Exhaust	BMBL4: D7	Install biological safety cabinets in such a manner that fluctuations of the room supply and exhaust air do not cause the biological safety cabinets to operate outside their parameters for containment.	BMBL5: D6	BSCs must be installed so that fluctuations of the room air supply and exhaust do not interfere with proper operations.	No Change	NC
87	BSL2	BSC Exhaust	BMBL4: D7	Locate biological safety cabinets away from doors, from windows that can be opened, from heavily traveled laboratory areas, and from other potentially disruptive equipment so as to maintain the biological safety cabinets' air flow parameters for containment.	BMBL5: D6	BSCs should be located away from doors, windows that can be opened, heavily traveled laboratory areas, and other possible airflow disruptions.	Generalization	FC
88	BSL2	Lab Ventilation			BMBL5: D7	Vacuum lines should be protected with High Efficiency Particulate Air (HEPA) filters, or their equivalent.	NPA	FC
89	BSL2	Lab Ventilation			BMBL5: D7	Filters must be replaced as needed.	NPA	PC
90	BSL2	Lab Ventilation			BMBL5: D7	Liquid disinfectant traps may be required.	NPA	FC
91	BSL2	Sinks/Eyewash	BMBL4: D8	An eyewash station is readily available.	BMBL5: D8	An eyewash station must be readily available.	No Change	NC
92	BSL2	Lab Construction	BMBL4: D9	Illumination is adequate for all activities, avoiding reflections and glare that could impede vision.			NCA	DC
93	BSL2	Lab Ventilation	BMBL4: D10	There are no specific ventilation requirements. However, planning of new facilities should consider mechanical ventilation systems that provide an inward flow of air without recirculation to spaces outside of the laboratory.	BMBL5: D9	There are no specific requirements on ventilation systems. However, planning of new facilities should consider mechanical ventilation systems that provide an inward flow of air without recirculation to spaces outside of the laboratory.	No Change	NC
94	BSL2	BSC Exhaust			BMBL5: D10	HEPA filtered exhaust air from a Class II BSC can be safely re-circulated back into the laboratory environment if the cabinet is tested and certified at least annually and operated according to manufacturer's recommendations.	NPA	FC
95	BSL2	BSC Exhaust			BMBL5: D10	BSCs can also be connected to the laboratory exhaust system by either a thimble (canopy) connection or a direct (hard) connection.	NPA	FC
96	BSL2	BSC Exhaust			BMBL5: D10	Provisions to assure proper safety cabinet performance and air system operation must be verified.	NPA	PC
97	BSL2	Decon.			BMBL5: D11	A method for decontaminating all laboratory wastes should be available in the facility (e.g., autoclave, chemical disinfection, incineration, or other validated decontamination method).	NPA	DC

NPA = Not Previously Addressed; NCA = Not Currently Addressed; DC = Documentation Change; FC = Facility Change; PC = Policy/Procedural Change; NC = No Change

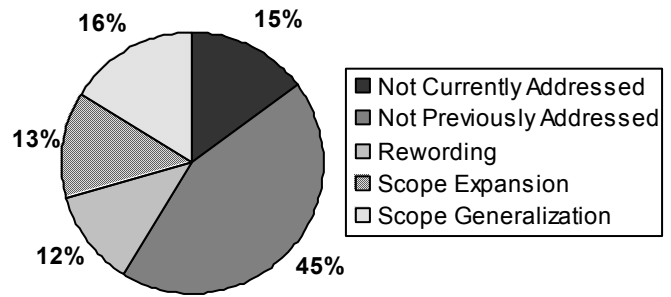
**Figure 2**

A graphical representation of the percent of total BMBL Section IV changes by Biosafety Level.



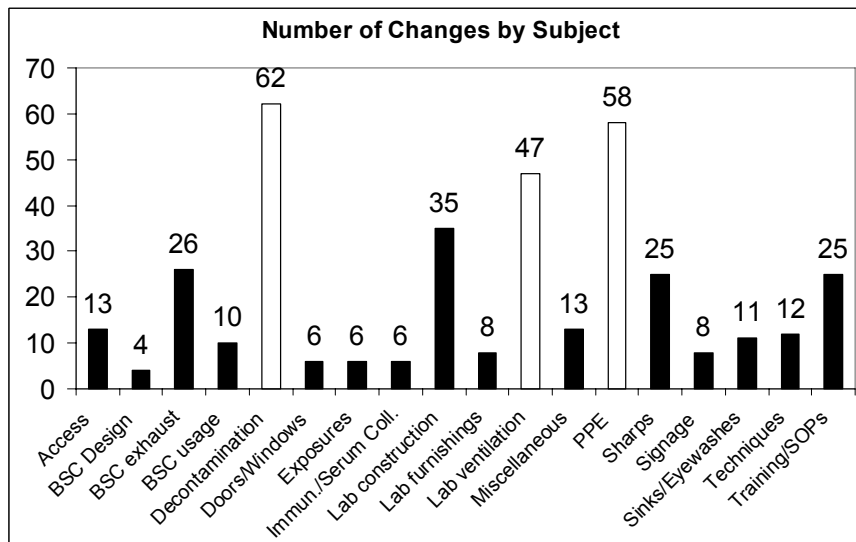
**Figure 3**

A graphical representation of the percent of total BMBL Section IV changes by type (n = 375).



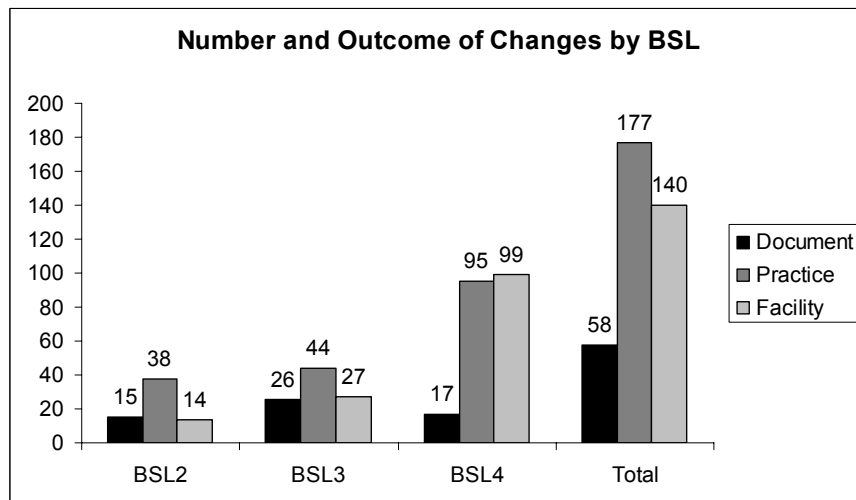
**Figure 4**

A comparison of the number of BMBL Section IV changes by subject. White bars indicate the three most common subjects for change.



**Figure 5**

A graphical representation of the number of document, practice, and facility changes between the 4th and 5th editions of BMBL by biosafety level.



### Figure 6

A summary of major changes between the 4th and 5th editions of BMBL Section IV, BSL2-BSL4.

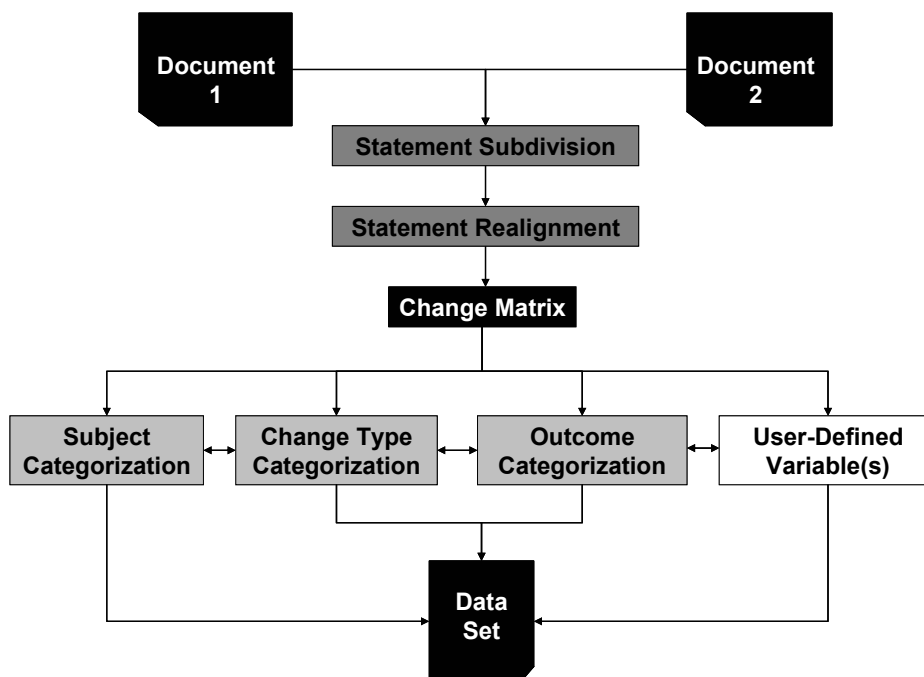
Biosafety Level	Major Changes	Applicable BMBL Citations
BSL2, BSL3, BSL4	The restriction of access to personnel who are at risk of acquiring infection is not addressed in BMBL5. BMBL5 states that all lab personnel should be provided with information regarding "immune competence and conditions that may predispose them to infection." Lab personnel are also encouraged to self-identify.	<b>BMBL4:</b> BSL2 B1; BSL3 B2; BSL4 B1. <b>BMBL5:</b> BSL2 A11; BSL3 A11; BSL4 A11.
BSL2, BSL3	"Laboratory personnel must be provided with medical surveillance."	<b>BMBL5:</b> BSL2 B2; BSL3 B3.
BSL2, BSL3, BSL4	"Incidents that may result in exposure to infectious materials must be immediately evaluated and treated according to procedures described in the laboratory biosafety safety manual."	<b>BMBL5:</b> BSL2 B8; BSL3 B8; BSL4 B8.
BSL2	"All procedures involving the manipulation of infectious materials that may generate an aerosol should be conducted within a BSC or other physical containment devices."	<b>BMBL5:</b> BSL2 B10
BSL2, BSL3, BSL4	Enhanced guidance on eye and face protection use, decontamination and disposal (See Citations).	<b>BMBL5:</b> BSL2 C3; BSL3 C3; BSL4 C(A)3
BSL2, BSL3, BSL4	Enhanced guidance on glove selection, use, and disposal (See Citations).	<b>BMBL5:</b> BSL2 C4; BSL3 C4; BSL4 C(A)4, C(B)3, C(B)4
BSL2	"Vacuum lines should be protected with High Efficiency Particulate Air (HEPA) filters, or their equivalent. Filters must be replaced as needed. Liquid disinfectant traps may be required."	<b>BMBL5:</b> BSL2 D7
BSL2, BSL3, BSL4	Enhanced guidance on Class II BSC exhaust (See Citations).	<b>BMBL5:</b> BSL2 D10; BSL3 D10; <b>BMBL4:</b> C(B)1, D(A)10, D(B)10.
BSL3	"Laboratory doors must be self closing and have locks in accordance with the institutional policies."	<b>BMBL5:</b> BSL3 D1
BSL3	"If the laboratory is segregated into different laboratories, a sink must also be available for hand washing in each zone."	<b>BMBL5:</b> BSL3 D2
BSL3	Enhanced guidance on HEPA filtration of laboratory exhaust air (See Citation).	<b>BMBL5:</b> BSL3 D14
BSL4	"Mechanical pipetting devices must be used."	<b>BMBL5:</b> BSL4 A4
BSL4	"The interior of the Class III cabinet as well as all contaminated plenums, fans and filters must be decontaminated using a validated gaseous or vapor method."	<b>BMBL5:</b> BSL4 B7-b
BSL4	Enhanced guidance on autoclave design and operation (See Citation).	<b>BMBL5:</b> BSL4 B10
BSL4 (cabinet lab)	Enhanced guidance on Class III BSC design, exhaust, and usage in the cabinet laboratory (See Citation).	<b>BMBL5:</b> BSL4 C(A)1.
BSL4 (cabinet lab)	Enhanced guidance on personal and protective clothing usage and decontamination in the cabinet laboratory (See Citation).	<b>BMBL5:</b> BSL4 C(A)2.
BSL4 (cabinet lab); BSL4 (suit lab)	"An automatically activated emergency power source must be provided at a minimum for the laboratory exhaust system, life support systems, alarms, lighting, entry and exit controls, BSCs, and door gaskets. Monitoring and control systems for air supply, exhaust, life support, alarms, entry and exit, and security systems should be on an uninterrupted power supply (UPS)."	<b>BMBL5:</b> BSL4 D(A)1, D(B)1.
BSL4 (cabinet lab)	"All sinks in the room(s) containing the Class III BSC and the inner (dirty) change room must be connected to the wastewater decontamination system."	<b>BMBL5:</b> BSL4 D(A)2
BSL4 (cabinet lab); BSL4 (suit lab)	Enhanced guidance on liquid and gas services (See Citations).	<b>BMBL5:</b> BSL4 D(A)3, D(B)3.

**Figure 6 (Con't.)**

Biosafety Level	Major Changes	Applicable BMBL Citations
BSL4 (cabinet lab)	"Redundant supply fans are recommended. Redundant exhaust fans are required."	<b>BMBL5:</b> BSL4 D(A)9
BSL4 (cabinet lab)	"The design of the HEPA filter housing must have gas-tight isolation dampers; decontamination ports; and ability to scan each filter assembly for leaks."	<b>BMBL5:</b> BSL4 D(A)9
BSL4 (cabinet lab)	"Class III BSCs must be directly and independently exhausted through two HEPA filters in series."	<b>BMBL5:</b> BSL4 D(A)9
BSL4 (cabinet lab); BSL4 (suit lab)	"Access to the exit side of the pass-through shall be limited to those individuals authorized to be in the BSL-4 laboratory."	<b>BMBL5:</b> BSL4 D(A)11, D(B)11.
BSL4 (cabinet lab); BSL4 (suit lab)	"Gas and liquid discharge from the autoclave chamber must be decontaminated. When feasible, autoclave decontamination processes should be designed so that over-pressurization cannot release unfiltered air or steam exposed to infectious material to the environment."	<b>BMBL5:</b> BSL4 D(A)13; D(B)13
BSL4 (cabinet lab); BSL4 (suit lab)	"Provisions for emergency communication and access/egress must be considered."	<b>BMBL5:</b> BSL4 D(A)15, D(B)15.
BSL4 (suit lab)	"In the event of an emergency exit or failure of chemical shower system a method for decontaminating positive pressure suits, such as a gravity fed supply of chemical disinfectant, is needed."	<b>BMBL5:</b> BSL4 D(B)1
BSL4 (suit lab)	"Only laboratories with the same HVAC requirements (i.e., other BSL-4 labs, ABSL-4, BSL-3 Ag labs) may share ventilation systems if each individual laboratory system is isolated by gas tight dampers and HEPA filters."	<b>BMBL5:</b> BSL4 D(A)9, D(B)9.
BSL4 (suit lab)	"Autoclaves that open outside of the laboratory must be sealed to the primary wall."	<b>BMBL5:</b> BSL4 D(B)13

**Figure 7**

A flow chart representing the utility of the BMBL change matrix methodology for future BMBL and other regulatory and/or guidance document updates.



unique challenge since the revision summaries of rapidly and dramatically changing guidance documents are often scant or non-existent. The change matrix we have developed is intended to be a resource for biological safety officers, investigators, and others with a vested interest in biosafety to assist in the identification of the issues most pertinent to their facility or institution. Individual statements or statement pairs have been presorted based on a number of criteria therefore allowing the individual user the freedom to filter the data based on their specific needs. For instance, an individual primarily interested in facility changes affecting laboratory exhaust requirements may sort through the changes based on those specific criteria.

The change matrix we have created presents a systematic and streamlined methodology for identifying changes in the Laboratory Biosafety Level Criteria sections between the fourth and fifth editions of BMBL. An overview of this process is represented graphically in Figure 7. We believe this methodology can also be applied to future revisions as well as to other elaborate guidance documents where a precise awareness of changing guidance is crucial to safety and regulatory compliance. In addition, the organization of the matrix makes it possible for the

individual user to add additional criteria (e.g., level of resource investment) and search for them against existing criteria.

## Authors' Note

The information contained herein does not necessarily represent the position of the federal government.

## References

- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, & National Institutes of Health. (1999). *Biosafety in microbiological and biomedical laboratories* (4th ed.). J. Y. Richmond & R. W. McKinney (Eds.). Washington, DC: U.S. Government Printing Office. Available at: [www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm](http://www.cdc.gov/od/ohs/biosfty/bmbl4/bmbl4toc.htm)
- U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, & National Institutes of Health. (2007). *Biosafety in microbiological and biomedical laboratories* (5th ed.). L. C. Chosewood & D. E. Wilson (Eds.). Washington, DC: U.S. Government Printing Office. Available at: [www.cdc.gov/od/ohs/biosfty/bmbl5/bmbl5toc.htm](http://www.cdc.gov/od/ohs/biosfty/bmbl5/bmbl5toc.htm)

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## Inactivation of *Francisella tularensis* Schu S4 in a Biological Safety Cabinet Using Hydrogen Peroxide Fumigation

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### Abstract

This study evaluated the inactivation of *Francisella tularensis* Schu S4 on various materials (acrylic, glass, polyamide, polyethylene, polypropylene, silicone rubber, and stainless steel) using hydrogen peroxide fumigation of a Class III Biological Safety Cabinet (BSC III). A suspension of *F. tularensis* Schu S4 ( $7 \times 10^7$  CFU) was dried on seven different types of test surfaces and exposed to vaporous hydrogen peroxide (VHP) fumigation for a contact time of two hours. Qualitative growth assessment showed that VHP exposure inactivated *F. tularensis* on all replicates of the seven test materials up to four days post-exposure. The effectiveness of VHP fumigation on the growth of biological indicators (*Bacillus subtilis* or *Geobacillus stearothermophilus*) and spore strips (*Bacillus atrophaeus*) was evaluated in parallel as a qualitative assessment of decontamination. At one and four days post-exposure, decontaminated biological indicators and spore strips exhibited no growth,

while the non-decontaminated samples displayed growth. This study provides information for using VHP fumigation as an alternative approach for the decontamination of virulent *F. tularensis* when the current accepted method of 10% household bleach followed by 70% alcohol may not be practical for decontamination of a BSC III.

### Introduction

The gram-negative coccobacillus, *Francisella tularensis* (formerly known as *Pasteurella tularensis*), is the etiologic agent of the zoonotic disease tularemia. *Francisella tularensis* is classified as a Category A select agent due to its infectivity and capacity to cause illness and death, thus heightening the concern of using this microorganism as a potential biological weapon (Dennis et al., 2001; Peterson & Schriefer, 2005). Such concerns have prompted decades of research investigating and developing vaccines and medical countermeasures against *F. tularensis* infection (Ellis et al., 2002).