Biosafety Cabinet Selection in the Context of Risk Assessment

Deciding Which Biological Safety Cabinet (BSC) Works Best for Your Lab Based on Your Overall Risk Assessment

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Conducting a risk assessment is one of the first steps that is recommended before performing new experiments that may expose workers to hazardous conditions or materials[1-3]. However, you may be wondering what is a risk assessment, and how do I conduct an appropriate one for my biological materials work? In this eBook, we will discuss what a risk assessment entails, what information you will need to perform one, how to mitigate risks, and how the selection of your biosafety cabinet fits into your overall risk assessment and risk control measures.

What is a Risk Assessment?

A risk assessment is the process that evaluates the likelihood (chance/probability) and consequence (severity) of exposure to hazards present in the workplace, including laboratories[3]. This can include biological, chemical, radiological, nuclear, physical, or other hazards that may cause injury or illness from an exposure or release. Risk assessments can be completed by an individual with input from several others, especially leadership and subject matter experts. However, they are best completed by a team of individuals who fully understand all aspects of the hazards, the staff capabilities, and the facility and equipment features, where ever possible[1,3].

For the purposes of this description, we will focus on hazards associated with biological materials, but a similar process can be completed for other types of hazards. The Centers for Disease Control and Prevention (CDC), National Institutes of Health (NIH), and the World Health Organization (WHO) all provide information on how to conduct a risk assessment[1-3].

The steps vary by organization but generally seek to:

1. Assess the hazards associated with specific agents and with specific laboratory procedures
2. Determine and implement control measures
3. Provide ongoing review of the remaining risks and effectiveness of control measures[1-3]

Features of the microbial agent can impact the consequence (or severity), as well as the likelihood (or chance/probability), of an exposure or release. Agents with a low infectious dose, that are highly transmissible, cause serious disease, have limited or no prophylaxis/treatment, and/or are exotic to the area of use may result in a higher consequence. Agents that spread efficiently, such as through aerosols, are environmentally stable, and that much of the population is susceptible to may be more likely to cause an exposure or release[1-3].

Agent Hazard Identification Resources

To learn more about specific microbes including their hazards, the severity of infection, and suggested containment practices for working with them, consider reviewing:

**The details and information provided in these third-party resources are the responsibility of the organization that has created them. The author and sponsor of this article are not responsible for the content provided therein.*

CDC/NIH Biosafety in Microbiological and Biomedical Laboratories, 6th Edition, Section VIII

Click Here

This section of the Biosafety in Microbiological and Biomedical Laboratories (BMBL) contains information on specific bacterial, fungal, parasitic, rickettsial, viral, and arboviral agents, toxins, and prion disease-causing agents. It contains general agent information, laboratory-acquired infections, modes of transmission, pertinent laboratory safety and containment considerations and information about vaccines and agent transfer, if available.

ABSA Risk Group Database

Click Here

This database includes bacterial, viral, fungal, and parasitic agents in a searchable format that lists the risk group an agent has been assigned according to several international sources. It also denotes whether the agent is a human, animal, and/or plant pathogen, if known, and whether it is listed by the CDC or United States Department of Agriculture (USDA) as a select agent.

Public Health Agency of Canada, Pathogen Safety Data Sheets

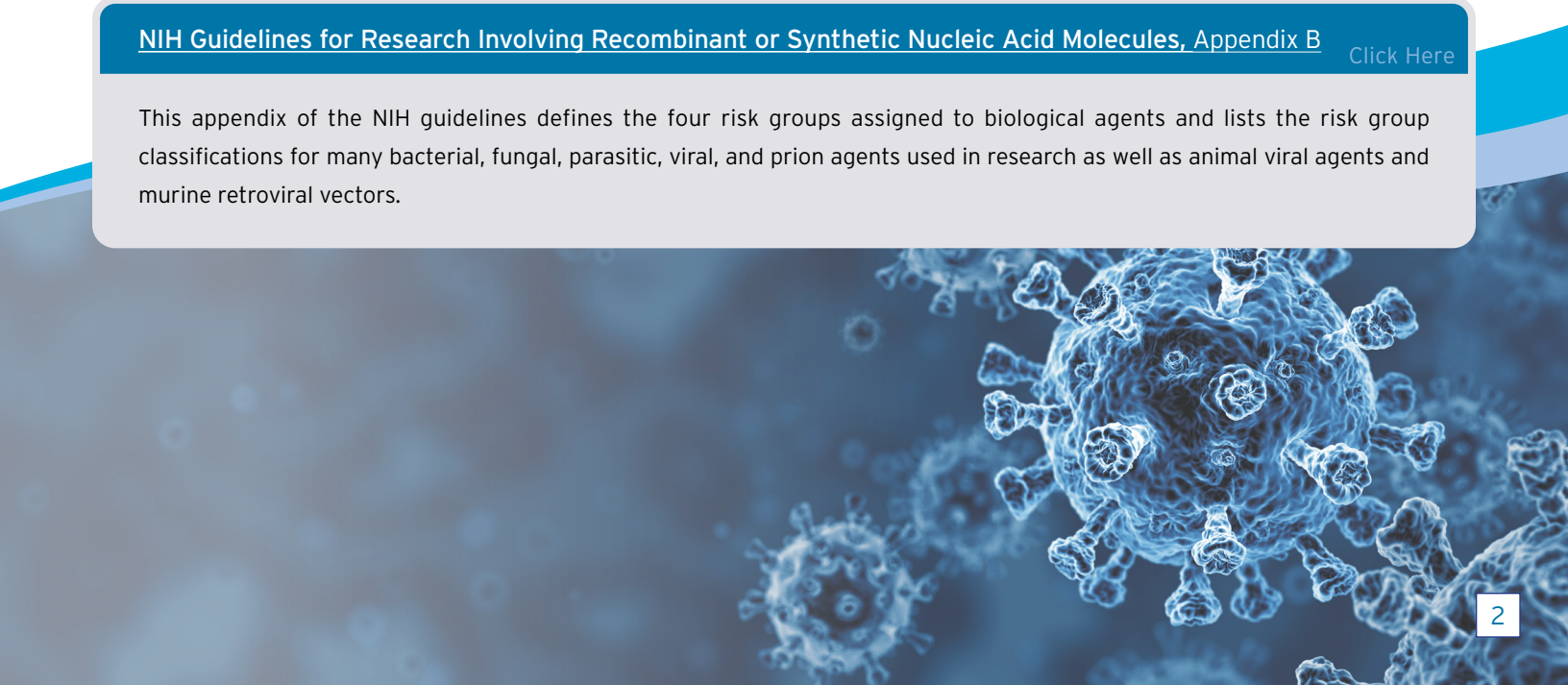
Click Here

Pathogen Safety Data Sheets (PSDS) are, in essence, the microbial version of chemical safety data sheets (SDS), formerly material safety data sheets (MSDS). For each listed microorganism, information is provided in nine distinct sections that cover that agent's characteristics, how the agent spreads and what hosts it can infect, its level of stability, how to monitor and treat or prevent infection, if laboratory-acquired infections have been identified, containment recommendations, and how to store and dispose of that agent.

NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules, Appendix B

Click Here

This appendix of the NIH guidelines defines the four risk groups assigned to biological agents and lists the risk group classifications for many bacterial, fungal, parasitic, viral, and prion agents used in research as well as animal viral agents and murine retroviral vectors.



Procedural Risk Factors and Resources

Once the agent(s) have been characterized, then ways in which that material is going to be handled can be assessed to determine the initial level of risk of the work. Certain laboratory procedures may also increase the likelihood and consequence of exposure or release. Processes that include generation of aerosols, use of sharps, animal handling, untrained or poorly trained staff, and facility or equipment deficiencies may increase the likelihood of exposure. Laboratory work that includes genetic modification of agents or use of large quantities or high concentrations of agents may also contribute to increased severity of exposure or release[1-3].

The overall risk is then calculated by plotting the likelihood (from very unlikely to highly likely) and consequence (from minor to severe) of exposure[3]. The resulting level of risk will be subjective and requires consideration by individuals with knowledge of the potential hazards. Your organization's leadership should also be involved in the considerations. In some cases, an unlikely event thought to be very severe may require several control measures, whereas a moderately likely event thought to be very minor may only require a few controls to reduce risk to an acceptable level. The acceptable level of risk and necessity for reducing potential risk will ultimately depend on your specific organization and the individuals performing the lab work, so all stakeholders must be involved when conducting a risk assessment wherever possible. Risk assessments are meant to be cyclical and include periodic evaluation of the effectiveness of all employed control measures (described in detail below) in minimizing risk to an appropriate level[1,3]. This review process then feeds back into the beginning of the risk assessment cycle if the hazards and risks are not being appropriately addressed or any features of the hazards change.

To learn more about laboratory procedure hazards, how to conduct a risk assessment, and find risk assessment templates, consider reviewing:

CDC/NIH Biosafety in Microbiological and Biomedical Laboratories (BMBL), 6th Edition, Section II

Click Here

This section of the BMBL describes the importance of risk management, how to conduct a risk assessment, what factors to consider in various steps of the process, how to communicate those risks, and the importance of developing a safety culture throughout the organization.

NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules, Section II

Click Here

This section of the NIH Guidelines contains information on the characterization of agents into risk groups and what to consider when conducting a risk assessment. Additionally, it describes ways to contain recombinant or synthetic nucleic acid molecules using biological barriers beyond standard practices and physical or facility barriers described in the BMBL.

WHO Laboratory Biosafety Manual: Risk Assessment Monograph

Click Here

This monograph contains detailed information on how to conduct a risk assessment, factors that impact the level of risk, ways to reduce risk, and examples of strategies used to implement risk assessments. This document also provides useful fillable templates for conducting risk assessments with some completed examples of risk assessments.

How Can I Reduce or Eliminate Identified Risks?

Once the initial risk assessment has been created, you can now determine ways to either eliminate the hazard or minimize the likelihood and/or consequence of exposure to the hazard. Note that the acceptable level of risk to one organization may be different than that of another organization based on their own risk tolerance and other factors, such as staffing, level of training, and facility specifics as mentioned above. Therefore, risk assessments and mitigation strategies must be specific to individual organizations and should not simply be transferred from one institution to another. The process of reducing risk is often called risk mitigation and involves application of control measures represented in the National Institute for Occupational Safety and Health (NIOSH)'s Hierarchy of Controls[4].

Class II Type A2 Biosafety Cabinet

This hierarchy contains five levels of controlling exposure to hazards listed from most to least effective[4]:

1. **Elimination** removes the hazard from the work entirely[4]. It may not be possible to use this control measure in some instances, especially when working with biological materials that may be hazardous by their nature but the work is necessary.
2. **Substitution** replaces the hazard with a less hazardous alternative[4]. This could be accomplished by using a less infectious strain of an organism that acts similarly to the organism of interest.
3. **Engineering Controls** physically modify equipment, facilities, and/or processes to separate personnel from the hazard[4]. For instance, using a biological safety cabinet (BSC) or other physical containment device to protect individuals from potentially infectious aerosols generated while working. Safety equipment, including BSCs, are considered primary barriers to enhance personnel and environmental protection, whereas laboratory facilities are considered secondary barriers[1].
4. **Administrative Controls** change the way the work is done[4]. These controls include creation of standard operating procedures (SOPs), personnel training, equipment maintenance, and other policies relating to how and when the work is performed.
5. **Personal Protective Equipment (PPE)** physically protects the individual by covering possible routes of exposure[4]. PPE can include different types of gloves, body coverings, head and face coverings, respiratory protection, and other forms of protection.

When working with biohazardous materials, the most common control measures include engineering controls, administrative controls, and various PPE. A combination of controls from each of the above levels may be selected to collectively reduce the likelihood and/or severity of exposure to biological materials to an acceptable level. For instance, when working with biological materials in a biosafety cabinet (engineering controls), you may follow your research-specific SOPs and previous BSC training (administrative controls), and wear gloves, safety glasses, and a lab coat (PPE).

How Can I Reduce or Eliminate Identified Risks? (cont.)

The above three control measures all depend, not only on the specific control or piece of equipment, but also on the effort of the individuals using them. Therefore, they are ranked as less effective and less protective than elimination or substitution[4]. Engineering controls, like BSCs, require routine maintenance, cleaning, certification, and proper operational technique (such as avoiding airflow or air curtain disruptions while working) to ensure user protection. Administrative controls including SOPs and personnel training along with work procedures require individuals to create and follow them appropriately to reduce risk of exposure. Furthermore, PPE must fit the individual and be worn correctly at all times to be considered protective. There is no single "catch-all" for risk mitigation that can eliminate all risk, other than abstaining from hazardous work entirely.

The CDC/NIH's BMBL defines four biosafety levels from biosafety level 1 (BSL-1) through biosafety level 4 (BSL-4) that each build upon the previous level and increase the level of protection provided for personnel, the environment, and the community. These biosafety levels include standard microbiological practices, special practices needed for unique agent handling risks, safety equipment, and laboratory facilities that are recommended to safely work with agents at that level of containment[1]. Risk groups, which describe the relative level of risk of the agent to individuals and/or the environment, are NOT synonymous with biosafety levels, which describe containment needs to safely work with the agent, but may be a good starting point for determining the necessary biosafety practices. Agents classified within a specific risk group will often be handled at their corresponding biosafety level. However, the biosafety level could be higher or lower than the risk group depending on a risk assessment that accounts for any modifications to the agent or specific procedures that may be performed with the agent[1,2].

Where Can I Find Biosafety and Risk Assessment Assistance?

If you need assistance in conducting a risk assessment or selecting appropriate risk mitigation measures, consider reaching out to a professional with experience in risk assessments and the hierarchy of controls. ABSA International and the IFBA both have mentoring programs to help those who are new to the field of biosafety or are expanding their biosafety skills into new areas.

More information on these programs can be found at:

1. **ABSA Mentoring Program**
2. **IFBA Global Mentorship Program**

Both organizations maintain a running list of professionals that have been certified in biosafety (ABSA Professional Credentials in Biosafety) and biorisk management, biosecurity, biosafety cabinet selection, installation, safe use, and other related topics (IFBA Directory of Certified Professionals). Additionally, there are several private organizations and paid consultants that can be contracted to help with risk assessments and selection of exposure control methods.

The American Biological Safety Association (ABSA) International and the International Federation of Biosafety Associations (IFBA) host and promote events that may assist individuals in learning more about biosafety topics and conducting risk assessments.

Information on these events can be found through:

1. **ABSA's Events Calendar**
2. **IFBA's Upcoming Events Webpage**

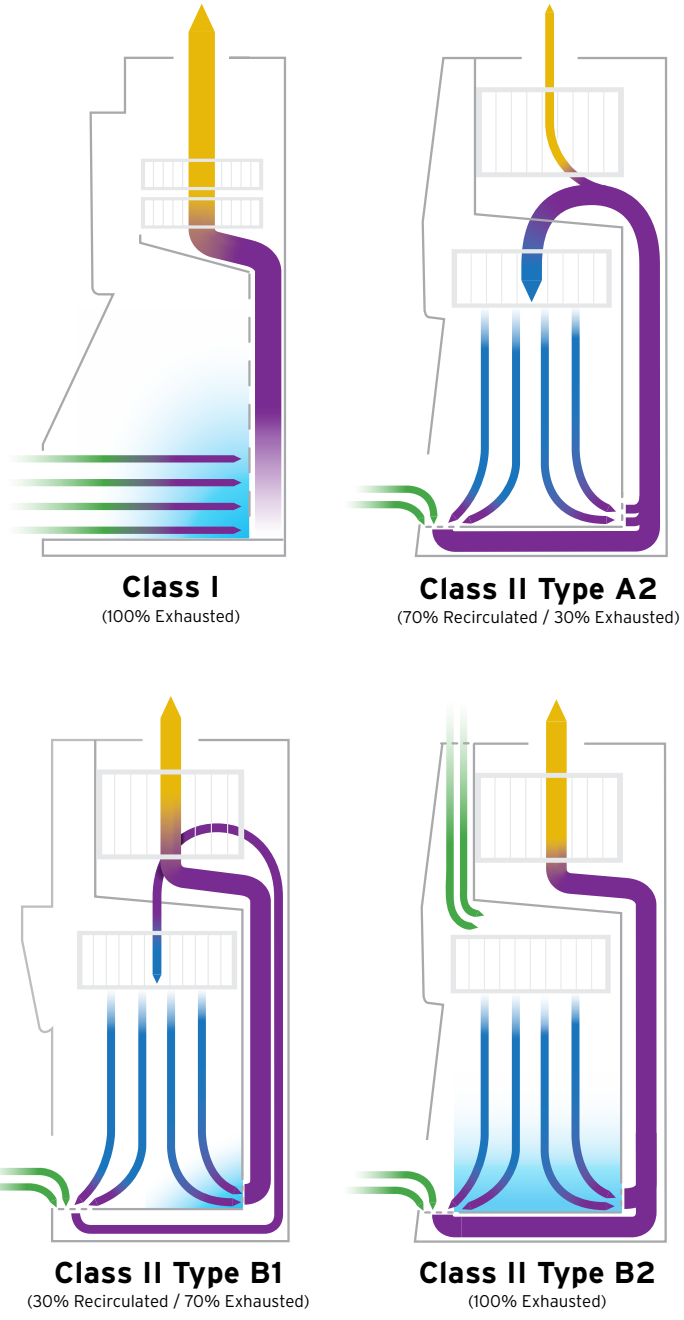
These organizations support professionals not only by hosting educational events and providing mentoring opportunities, but they also facilitate professional networking, development, and capacity building. ABSA International maintains a list of affiliate organizations by region throughout the world that are made up of members who are involved or interested in biosafety. These regional groups also host events for education and networking for their membership where you may be able to connect directly with other members for assistance with risk assessments.

How Does My Risk Assessment Fit into Biosafety Cabinet Selection?

When considering the use of engineering controls, specifically biosafety cabinets, it is important to understand the different classes and types of BSCs, how they differ, and what limitations they may have based on the proposed work to be performed.

Broadly speaking, there are three classes of BSCs (Class I, Class II, and Class III) that offer varying levels and types of protection[1,5,6]. Class I cabinets function similarly to chemical fume hoods where they pull room air into the cabinet, pass it through the work zone, and then exhaust that air without recirculating it. However, these BSCs do so only after passing that exhausted air through a HEPA filter to capture any microbial aerosols. Class I cabinets protect personnel and the environment but do not provide HEPA-filtered air prior to reaching the work zone for the product's protection[1,5,6]. If your risk assessment identifies a need to protect the product from external contaminants, you may need to select a Class II or Class III biological safety cabinet.

Unlike Class I biosafety cabinets, Class II BSCs provide personnel, environment, and product protection by utilizing an additional HEPA filter to provide clean air to the work zone to safeguard the product from cross-contamination. Within Class II, there are five types of BSCs: A1, A2, B1, B2, and C1. These types mostly differ in the percentage of air that is recirculated versus exhausted, how they are connected to the building's exhaust system (if at all), and whether they can accommodate work with hazardous and/or volatile chemicals[1,5,6]. Class II, Type A1, A2, and C1 BSCs do not require connecting to the building exhaust system so, if it is determined that the materials being worked with can safely be exhausted back into the room after passing through only a HEPA filter, these BSC types may be selected. They can also be ducted through a canopy/thimble (Type A1 & A2 BSCs) or other ventilated connection (Type C1 BSCs) if needed based on a risk assessment, including for the use of minuscule amounts of volatile chemicals. However, Class II, Type B1 and B2 BSCs must be connected directly to the building exhaust system[1,6]. The method of connection to the building exhaust system can influence the overall HVAC system's performance, the room's air balancing, the BSC's energy use, and the ability to use small or minute quantities of volatile chemicals in the cabinet. Since HEPA filters allow chemical vapors to pass through them, these chemicals may be able to concentrate within a BSC that recirculates a portion of the air through the supply HEPA filter (Type A1, A2, B1, C1 BSCs). Class II, Type B2 biosafety cabinets do not recirculate any of their air so they may need to



be selected based on the properties of chemicals or radionuclides that are going to be used within the BSC[1,6]. Your risk assessment should identify which, if any, of these features are needed to protect individuals from the work they are performing within the Class II BSC or whether a higher level of protection is needed.

Class III biosafety cabinets provide the highest level of personnel and environmental protection because they are gas-tight, and all exhausted air must pass through two HEPA filters in series or one HEPA filter and an air incinerator prior to being released[1]. They also provide product protection and are typically used for highly hazardous work involving potentially infectious aerosols[1,5]. There are additional logistical considerations for using a Class III BSC above and beyond those for Class I and Class II BSCs including exhaust system requirements, laboratory placement, materials handling and transfer, work practices, and personnel training.

The class of BSC needed for working with biological materials is not necessarily directly aligned with the biosafety level needed to manage the research risks. BSL-1 laboratories do not exclusively use Class I BSCs. The cabinet class selection is dependent on the types of protection needed for the work. For instance, Class II BSCs, which provide all three types of protection, can be used with risk group 1 through risk group 4 agents at BSL-1 through BSL-4[1,6]. However, at BSL-4, the use of Class II BSCs would dictate that personnel wear additional PPE in the form of a protective suit that is positively pressured and supplies breathing air and work in a specially designed laboratory[1].

To learn more about specific classes and types of BSCs and questions to answer when considering the necessary features of your BSC, consider reviewing:

WHO Laboratory Biosafety Manual: Biological Safety Cabinets and Other Primary Containment Devices Monograph Click Here

This monograph provides information on types and classes of BSCs and other primary containment devices. The WHO also outlines how to work in these devices, the importance of directional airflow and methods of exhaust (recirculation and ducted), and how to select a BSC. There are informative graphics and tables that provide visual depictions of airflow and containment features by BSC class and BSC characteristics.

CDC/NIH Biosafety in Microbiological and Biomedical Laboratories, 6th Edition, Section II, Appendix A Click Here

This appendix of the BMBL introduces the classes and types of BSCs and important considerations for their selection, such as volatile chemical use, radiological material use, percentage of air that is recirculated, and exhaust configuration. The appendix also includes factors to consider in your risk assessment, best practices for working in a BSC, laboratory placement of BSCs, and BSC certification information. It includes graphics and tables of airflow and exhaust configurations as well as comparisons of classes of BSCs based on biosafety levels and use of chemical or radiologic material.

NSF/ANSI 49 -2020 Biosafety Cabinetry: Design, Construction, Performance, and Field Certification Informative Annex 1

This document provides useful information relating to risk assessments specific to the use and selection of biosafety cabinets. It covers the basics of BSC function, exhaust configurations, characteristics of classes and types of BSCs, laboratory placement of BSCs, decontamination of work surfaces, best practices for working in a BSC, and decommissioning BSCs. Additionally, this annex lists specific stages and questions to be included in a risk assessment for BSC selection relating to the types of protection needed (personnel, product, environmental), the types of work to be performed, if chemical use is planned, and exhaust system requirements. The document also includes graphics and tables contrasting BSC airflow, features, and exhaust configurations.

BSC Selection, Certification, and Resources

Once you have identified the level of protection needed, reviewed which class/type of cabinet is most appropriate, and incorporated your specific work's risk assessment into BSC selection, there are additional thoughts to consider about choosing the specific BSC that you will designate for the work. Since BSCs are mechanical devices with many moving parts, they must be properly installed and adequately maintained throughout their lifespan to ensure the constant level of protection needed for your work. If you do not already own the cabinet class/type dictated by your risk assessment, you can purchase a new or used BSC. For Class II cabinets, NSF can test and certify specific models of BSCs to the NSF/ANSI 49 certification standard to ensure they are properly designed and constructed. This is referred to by NSF as "cabinet design certification" because it confirms that the designated BSC model meets the stringent requirements of NSF/ANSI 49-2020 Annex N-1[6]. If you are looking for a Class II BSC, consider searching on the NSF Certified Biosafety Cabinetry list to find certified BSC manufacturers and model numbers before acquiring a new unit.

Biological safety cabinets must also meet specific performance standards and be certified during installation by a qualified field certifier. The certification process should be repeated at least annually to ensure proper functionality. This on-site certification is referred to by NSF as the "cabinet field certification" because it involves a formal verification of the performance of the installed BSC to ensure that it still meets the safety requirements of NSF/ANSI 49-2020 Annex N-5[6]. The make, model, specific features, and maintenance history of that cabinet can be evaluated for suitability with the help of the manufacturer and/or an accredited biosafety cabinet field certifier. NSF maintains a list of accredited biosafety cabinet field certifiers that have met either their Basic Accreditation Program or their Enhanced Accreditation Program by name and location. It is also important to understand these certifications to review information provided by manufacturers about certification and the individual or group conducting the performance testing and field certification of your BSC.

To learn more about biosafety cabinet certification, consider reviewing:

CDC/NIH Biosafety in Microbiological and Biomedical Laboratories (BMBL), 6th Edition, Appendix A — Click Here

This appendix describes the history and evolution of Class II BSC standards and specifications for design, construction, performance, and the importance of field certification.

NSF/ANSI 49 -2020 Biosafety Cabinetry: Design, Construction, Performance, and Field Certification — Click Here

This standard fully describes the design, construction, performance, and testing requirements for Class II BSCs to ensure that they provide the level of protection intended. This standard must be purchased to read.

NSF Webinar: Biosafety Cabinetry Testing, Certification and Field Certifier Accreditation Overview — Click Here

This webinar introduces risk assessments and biosafety levels, the classes and types of BSCs, identified user, maintenance and facility issues with BSCs, and the importance of BSC field certification.

BSC Manufacturer Considerations and Overall Conclusions

Although it may be tempting to ask the BSC manufacturer you are considering purchasing from to select which class and type of BSC you should use, this approach is likely to fail to meet your organization's needs. This is because the manufacturer does not and cannot understand all the factors that went into your risk assessment for BSC selection, what future work may be proposed for the cabinet, and the risk tolerance of your organization. Once your organization's risk assessment has determined which class and type of cabinet meets your research needs, the manufacturer can then help with the selection of a particular model and relevant features that will complement your risk mitigation strategies.

Conducting a risk assessment for work with biological materials is the critical first step in evaluating laboratory activities and their risks to health and safety. The risk reduction measures selected by your organization will also depend on many factors including the specific agents in use, the risks of the work to be performed, and the organization's risk tolerance. A multi-layered approach of control measures based on NIOSH's hierarchy of controls should be selected where engineering controls (including BSCs) may be identified as one part of an overall risk reduction strategy. There are many available resources to assist you in conducting a risk assessment, selecting appropriate risk reduction methods, and evaluating those methods used to mitigate the risks associated with manipulating biological materials in research, clinical, public health, or pharmaceutical settings.

References:

1. CDC/NIH Biosafety in Microbiological and Biomedical Laboratories (BMBL) 6th Edition: https://www.cdc.gov/labs/BMBL.html
2. NIH Guidelines for Research Involving Recombinant or Synthetic Nucleic Acid Molecules (NIH Guidelines): https://osp.od.nih.gov/biotechnology/nih-guidelines/
3. WHO Laboratory Biosafety Manual: Risk Assessment monograph: https://www.who.int/publications/i/item/9789240011458
4. National Institute for Occupational Safety and Health (NIOSH) Hierarchy of Controls: https://www.cdc.gov/niosh/topics/hierarchy/default.html
5. WHO Laboratory Biosafety Manual: Biological Safety Cabinets and Other Primary Containment Devices monograph: https://www.who.int/publications/i/item/9789240011335
6. NSF/ANSI 49 -2020 Biosafety Cabinetry: Design, Construction, Performance, and Field Certification Informative Annex 1: https://webstore.ansi.org/Standards/NSF/NSFANSI492020Annex