**A Guide to Selecting the Right Biological Safety Cabinet (BSCs) for Laboratory Use**

## ABSTRACT

This article provides a structured approach to Biological Safety Cabinets (BSCs) selection by evaluating cabinet classes, types, airflow patterns, containment capabilities, and application-specific requirements. BSCs provide a controlled environment to protect personnel and the laboratory setting from exposure to pathogens, ensuring a safe working space. By aligning cabinet choice with biosafety level, work type, and regulatory standards, laboratories can minimize contamination risks and optimize safety outcomes. There are several types of BSCs, each differentiated by the level of biocontainment they provide to meet the requirements of specific biosafety levels. This article further explores various classes of biological safety cabinets, which are already well-known, their unique features, and their applications in different laboratory settings. Furthermore, the paper underscores the need for informed equipment selection to ensure laboratory safety and compliance with institutional and international biosafety guidelines.

**Keywords:** *Biological Safety Cabinets, Biosafety, Safety requirements, Biohazard, Biosafety levels, Personal protective equipment.*

**INTRODUCTION**

**What and Why Is a Biological Safety Cabinet (BSC) Crucial?**

Biosafety cabinets (BSCs) are a type of biocontainment equipment used in biological laboratories to protect the operator, the laboratory environment, and experimental materials from exposure to infectious aerosols and splashes when operating contagious materials such as bacterial strains, primary cultures, and diagnostic specimens.

While all three classes protect personnel and the environment, only Class II and III cabinets protect products. A BSC’s HEPA filter effectively traps infectious organisms and ensures that only microbe-free exhaust air is discharged from the cabinet.

As for biosafety cabinet applications, biosafety cabinets are widely used in scientific research, teaching, clinical testing, and production in microbiology, biomedicine, genetic engineering, and biological products.

Biosafety cabinets must be inspected by trained personnel regularly and be “certified” as safe for work involving infectious agents or toxins.

Biohazard is an infectious agent or part thereof that presents a real or possible hazard to the health of not only humans but also plants and animals (CDC 2020, OSHA, WHO). Biohazards are categorized by risk groups that correlate to biosafety level standards (BSL 1-4). These typically refer to the Biological Safety Cabinet.

The best source of operational guidance comes from your institution. The Centers for Disease Control give the requirements when working with agents or samples that you have in the laboratory. In addition, your institution may require additional compliance. Outside the USA, another guideline is the [WHO Biosafety Manual](https://www.who.int/publications/i/item/9789240011311) (WHO).

Understanding why Biological Safety Cabinets are required when working with biohazard samples is essential.

Biological Safety Cabinets (BSCs) are critical engineering controls used in laboratory environments to provide containment of biohazardous materials and protect laboratory personnel, the environment, in certain models, the integrity of the work material itself (CDC 2020; ASRP; George Washington UNI). Importantly, BSCs differ from chemical fume hoods, which are not suitable for biohazard containment; they would be dispersed into the environment and still bioactive (Princeton 2025; University of California 2025; Uni of Rocherster 2022).

A biological safety cabinet (BSC) or microbiological safety cabinet is an enclosed, ventilated laboratory workspace for safely working with materials contaminated with (or potentially contaminated with) pathogens requiring a defined biosafety level. Several different types of BSCs exist, differentiated by the degree of biocontainment they provide (CDC 2020).

Biological safety cabinets (BSCs) are essential components in a laboratory setting, designed to protect personnel, the environment, and experimental materials. Class II BSCs are widely used for procedures requiring sterile conditions, as they provide a contamination-free workspace through the use of laminar airflow and High-Efficiency Particulate Air (HEPA) filtration. These systems effectively prevent airborne particulates from entering or leaving the work area, thereby maintaining the sterility of testing products. Proper use of BSCs, combined with strict adherence to aseptic techniques and operational protocols, is critical to ensuring the accuracy of test results and the safety of laboratory operations. (CDC 2020; WHO 2020; U.S. Department of Health and Human Services, Public Health Service, & National Institutes of Health. (2019); Siegel 2007; Kruse 1991)

BSCs are certified for their efficiency and safe operation by professionals who follow specific standards and protocols. Certification ensures that a BSC is performing properly, especially in terms of airflow, HEPA filtration, and containment to protect the user, product, and environment. Certification is usually required annually or after relocation, repairs, or filter replacement (CDC 2020; NFS 2023).

**Classification of BSC**

The U.S. Centers for Disease Control and Prevention (CDC) classifies BSCs into **three classes** (CDC 2020).

BSC Class I

Class I cabinets provide personnel and environmental protection but no product protection. The air passes upwards through a high-efficiency particulate air (HEPA) filter before being exhausted. Biosafety Level 1 is for undergraduate and secondary educational training and teaching laboratories and for other laboratories that use nonpathogenic microorganisms.

Examples are *Bacillus subtilis*, *Naegleria gruberi*, and infectious canine Hepatitis virus. Thus, BSL-1 containment only requires a sink for hand washing.

BSC Class II

Class II and Class III biological safety cabinets provide personnel, environmental, and product protection.

Biological safety cabinets (BSCs), particularly Class II models, are integral to maintaining the sterility of testing products in laboratory settings. They are engineered to protect both personnel and products by providing a sterile environment that minimizes the risk of contamination during critical procedures such as sterility testing (WHO 2025; NIH 2023; Ecolab 2024; QUALIA Bioscience 2025; Wikipedia contributors 2024).

Class II BSCs are open-fronted enclosures, similar to Class I BSCs, in which the air enters the cabinet through the front opening to provide operator protection.

Biosafety Level 2 is appropriate for clinical, diagnostic, teaching, and other laboratories that deal with indigenous moderate-risk agents linked with human disease and are present in a community. Examples are the Hepatitis B virus, HIV, Salmonella, and Toxoplasma. These microorganisms may be used on the open bench if aerosol production is low. BSL2 level of compliance aligns well with the Occupational Safety and Health Administration (OSHA) (the oversight body for enforcement of safety and health legislation) standard when working with specimens that contain blood or blood traces. A thorough and comprehensive exploration of biosafety levels, safety practices, and regulatory standards for animal biosafety levels can be found in the CDC’s Biosafety in Microbiological and Biomedical Laboratories (CDC 2020).

*Types of Class II Cabinets*

There are **four types**(A1, A2, B1, B2 and C1) of Class II BSCs. The main differences between the types are the ratio of air exhausted from the BSC to the air recirculated within the BSC and the type of exhaust system present (NSF 2023; BSI 2000; Wikipedia 2016; DIN 2016).

To understand how BSCs work, we need to understand how they are built. The main components include the blower and plenum, the work area, and controls. The upper area has HEPA filters and a negative pressure design.

The work area is made of stainless steel, a dished work surface, and fixtures that provide easy access to tubing into the BSC. The control part can be located above the user area or at the line of sight for easy access.

The principles of operation use fans mounted in the cabinet to draw directional mass airflow around a user and into the air grille, protecting the operator. The air is drawn underneath the work surface and back up to the top of the cabinet, passing through the HEPA filters.

A column of HEPA-filtered, sterile air is also blown downward over products and processes to prevent contamination. Air is also exhausted through a HEPA filter, and depending on the type of Class II BSC, the air is either recirculated back into the laboratory or pulled by an exhaust fan through ductwork, where it is expelled from the building.

*Types A1 and A2 Cabinets (Class II BSC)*

The Type A1 cabinet, formerly known as Type A, has a minimum inflow velocity of 75 ft/min. The downflow air, considered contaminated, splits just above the work surface (the BSC's smoke split) and mixes with the inflow. This air is drawn through ductwork, up the back of the cabinet, which is then blown into a positive-pressure, contaminated plenum.

The Type A2 cabinet, formerly designated A/B3, has a minimum inflow velocity of 100 ft/min. All contaminated positive-pressure plenums are surrounded by a negative air pressure plenum. In other respects, the specifications are identical to those of a Type A1 cabinet (U.S. EPA; Deutsches Institut für Normung (DIN) 2016).

Class II Type A2 Safety Cabinets are often selected for applications for microbiology, cell culture, clinical research, healthcare, and life science research. They help ensure excellent protection of personnel, environment, and product protection, as well as protection from [cross-contamination](https://gmpinsiders.com/contamination-cross-contamination-and-mix-ups-in-pharmaceutical-manufacturing/).

*Types B1 and B2 Cabinets (Class II BSC)*

In contrast to the type A1 and A2 cabinets, Type B BSCs use single-pass airflow (air that does not mix and recirculate) also to control hazardous chemical vapors. Type B1 and B2 cabinets have a minimum inflow velocity of 100 ft/min, and these cabinets must be hard ducted to an exhaust system rather than exhausted through a thimble connection.

The Type B2 cabinet (also known as a Total Exhaust BSC) is expensive to operate because no air is recirculated within. Therefore, this type is mainly found in such applications as toxicology laboratories, where the ability to use hazardous chemistry safely is important.

Additionally, if the exhaust system for a Type B1 or B2 cabinet were to fail, contaminated air could flow into the laboratory. To mitigate this risk, cabinets of this type generally monitor exhaust flow, shutting off the supply blower and sounding an alarm if the flow is insufficient.

Type A2 and C1 cabinets can circulate air back to the lab or exhaust the air outside. Software, performance, and ergonomics are the main elements that impact BSC, and the newer designs improve sustainability, longevity, and safety.

For example, advanced designs (type C1) reduce overall exhaust air, and robust motors increase HEPA filter life. Cabinets are certified to the version of the standard they were designed. A 20-year-old cabinet is certified to a 20-year-old standard. Newer units are designed to current design standards.

Class II cabinets provide the most advanced features and innovative technology like smart protection, ergonomics, ease of use, smart cleaning, and disinfection.

Additionally, the standard USB data has an embedded capability to provide cloud-based connectivity. This enables customers to check the BSC status in real time and be alerted to critical issues via alarms and alerts. Maintenance requirements and the ability to interrogate the events log are also available.

*Latest Class II BSC Types*

Recent versions of Class II BSC (MSC-Advantage BSC) emphasize energy efficiency, reduced noise levels, and compliance with international biosafety standards such as NSF/ANSI 49 and EN 12469 (NSF/ANSI 2016; European Committee for Standardization 2000). Furthermore, they are designed to provide Smart Port convenience, Smart Clean windows design, and an LED control panel compared to old versions. The introduction of flexible cabinet types, such as the Type C1, marks a major innovation, allowing laboratories to switch between recirculating and total exhaust modes depending on the application. This versatility reduces the need for multiple cabinet types while maintaining high levels of containment and sterility.

The Thermo Scientific™ MSC-Advantage™ Class II Biological Safety Cabinet (BSC) exemplifies a fusion of advanced safety features, energy efficiency, and ergonomic design, catering to the stringent demands of modern laboratories. Equipped with dual DC motors, the cabinet achieves up to 68% energy savings compared to traditional AC motor-driven units, significantly reducing operational costs and heat emission. The proprietary Smart Flow™ technology ensures consistent airflow, while the Digital Airflow Verification (Dave) system provides real-time monitoring, alerting users to any deviations that could compromise safety. Ergonomics are central to the MSC-Advantage’s design, featuring a 10° sloped front for enhanced user comfort, low noise levels (<59 dBA) to minimize distractions, and a spacious work area with comfortable armrests. The Smart Clean™ front window design facilitates easy cleaning and equipment loading, while the intuitive control panel displays critical safety and performance data. Additionally, the Smart Port™ system organizes tubing and cables efficiently, and an optional programmable UV light extends bulb life and conserves energy. Certified to the EN 12469 safety standard by TÜV Nord, the MSC-Advantage BSC is available in four sizes (90 cm, 120 cm, 150 cm, and 180 cm), offering flexibility to suit various laboratory spaces and applications. Its design accommodates connection to external exhaust systems, providing protection when working with trace amounts of volatile toxic chemicals. Collectively, these features position the MSC-Advantage as a reliable and efficient solution for laboratories prioritizing safety, performance, and sustainability (Thermo Fisher Scientific 2025).

The latest BSC models are critical tools in ensuring laboratory safety, operational flexibility, and contamination control in evolving biomedical and industrial environments. Typical applications are routine research applications in cell culture, clinical research, life science research, and microbiology.

*Cytotoxic Cabinets*

Cytotoxic cabinets help ensure excellent protection when handling cytotoxic substances. They have a triple filter design for better filtration efficiency than regular class II biological safety cabinets.

Digital Airflow Verification (Dave) alerts, system self-checks, and performance status are provided on the full-color touchscreen. Furthermore, with enabled connectivity, the remote app provides all the data a technician needs. Routine maintenance, cleaning, and setup tasks in these cabinets are simplified.

Cytostatic safety cabinets are often selected for applications for work with hazardous drugs, CMR (carcinogenic, mutagenic, reprotoxic) substances, including preparation of hazardous drugs in healthcare compounding pharmacies and facilities complying with USP or other specialized procedures, particularly in Europe (European Commission 2022; ISO 2015; CDC 2000; Baker company 2010).

Class III Biological Safety Cabinets

The Class III cabinet, generally only installed in maximum-containment laboratories, is specifically designed to provide maximum protection when working with BSL-4 pathogenic agents.

The enclosure is gas-tight; all materials enter and leave through a dunk tank or double-door autoclave. Gloves attached to the front prevent direct contact with hazardous materials. Class III cabinets are sometimes called glove boxes.

They are typically fitted with a pass box (often independently ventilated) or dunk tank to facilitate the movement of potentially contaminated work materials in and out of the cabinet. An autoclave may also be attached for waste management, mainly in facilities with a maximum containment cabinet line (CDC 2000).

Clean Benches

Clean benches, or laminar flow hoods, are widely utilized in laboratory and industrial environments for procedures that require a sterile workspace but do not involve hazardous biological materials. These devices operate by directing HEPA-filtered air over the work surface in a unidirectional flow, effectively excluding airborne contaminants and maintaining a particle-free environment. Unlike BSCs, clean benches are designed solely for product protection and do not provide personal or environmental protection (CDC 2020; WHO 2020; US DHHS 2019; Esco Scientific; Kruse 1991; OSHA 2011). Clean benches meet ISO class 5 minimum conditions achieved in the work area and EU GMP Grade A work environment. They have many advantages, like Smart Ports, side windows, and intuitive control panels.

Typical applications for clean benches include media preparation, aseptic transfers, pharmaceutical quality control, tissue culture, cleanrooms, GMP suites, the assembly of sterile medical or electronic devices, food, cosmetic, and aerospace industries.

**Conclusion**

Selecting the appropriate Biological Safety Cabinet (BSC) is crucial for ensuring both personnel protection and experimental integrity in laboratory environments. This paper provides a structured approach to BSC selection by evaluating cabinet classes, types, airflow patterns, containment capabilities, and application-specific requirements. By aligning cabinet choice with biosafety level, work type, and regulatory standards, laboratories can minimize contamination risks and optimize safety outcomes. As BSC technology continues to evolve, laboratory personnel must remain informed about current models, certifications, and best practices. Ultimately, informed selection and proper use of BSCs are fundamental to maintaining a safe and compliant laboratory environment.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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