Protecting people and processes through cleaning and disinfection

Cleaning and disinfection protocols are an important aspect of many institutional and industrial operations. This has universally come to the forefront for organizations with the evolution of the COVID-19 pandemic across the globe in 2019.

While the COVID-19 pandemic resulted in a focus on cleaning and disinfection as a critical activity to protect people from becoming ill, these activities may have additional objectives for organizations depending on the nature of their business. This includes minimizing the risk of contamination to products or workplace environments in order to meet regulatory or health and safety requirements.

Cleaning and disinfection (C&D) are especially important in cases where aseptic conditions must be maintained. This is commonly found in healthcare, animal care, pharmaceutical manufacturing and food processing applications. Other applications where C&D plays an important role are in situations where there is environmental contamination from a material such as the SARS-CoV-2 virus (which causes COVID-19 disease) or some other contamination from a biological material like human blood at a trauma scene.

Cleaning and disinfection are two distinct elements of the process of making a known or potentially contaminated environment safe for occupancy. Cleaning focuses on removal of dirt and debris, whereas disinfection involves taking action to minimize or eliminate microbial contamination. Cleaning should precede disinfection in order to remove materials that may interfere with the effectiveness of the disinfection process.

The US Centers for Disease Control and Prevention (CDC) currently defines cleaning, disinfecting and sterilization as follows:

Cleaning refers to the removal of microbial contamination, dirt and impurities from surfaces. Cleaning does not kill microbes, but by removing them, it lowers their numbers and the risk of spreading infection.

Disinfecting refers to using chemicals to kill microbes on surfaces. This process does not necessarily clean dirty surfaces or remove microbes, but by killing microbes on a surface *after* cleaning, it can further reduce the risk of spreading infection.

Sterilization refers to the process that destroys or eliminates all forms of microbial life, including bacterial spores, by physical or chemical methods.

Detergents and cleaning agents are preparations intended to dissolve unwanted soils or contaminants, or to change the surface energy interaction between particles and a surface so they can be removed by mechanical means. A cleaning step is typically conducted prior to disinfecting to remove gross contamination that may interfere with the efficacy of antimicrobial agents.

For the purposes of this document, microbial contamination includes hazardous microorganisms, such as viruses, bacteria and fungi, that are capable of causing disease in humans. Hazardous microorganisms are also sometimes referred to as biohazardous agents or biohazards.

The susceptibility or resistance of a microorganism to disinfection is dependent on the type of biohazardous agent that is present. The following table displays this hierarchy of susceptibility:

Resistant	Level
Prions (Creutzfeldt-Jakob Disease)	Prion reprocessing
Bacterial spores *(Bacillus atrophaeus)*	Sterilization
Coccidia *(Cryptosporidium)*	Disinfection
Mycobacteria *(M. tuberculosis, M. terrae)*	*High*
Nonlipid or small viruses (polio, coxsackie)	
Fungi *(Aspergillus, Candida)*	*Intermediate*
Vegetative bacteria *(S. aureus, P. aeruginosa)*	*Low*
Lipid or medium-sized viruses (HIV, herpes, hepatitis B)	
Susceptible	

Source: CDC's "Guideline for Disinfection and Sterilization in Healthcare Facilities" (2008).

In the case of COVID-19 disease, humans are the source for the causal agent, the SARS-CoV-2 virus, and the resultant potential for biohazard contamination. Consequently, infected persons present the opportunity to contaminate the environments they occupy. Cleaning and disinfection of these environments is a major means of achieving disease containment and preventing the spread of infection. A similar need for C&D exists for other sources of environmental contamination in healthcare facilities or at the scene of trauma incidents. C&D also is performed as a preventative measure to ensure the quality and safety of food and pharmaceutical products.

Common types of antimicrobial agents and disinfection methods

Disinfection can be accomplished using several methods, including exposure of an item or surface to ionizing radiation, ultraviolet (UV) light, heat or chemical compounds. The focus of this document is to provide guidance on selecting protective apparel for the safe handling of chemical-based C&D products used for their antimicrobial activity.

Chemical family classes commonly used as active ingredients in C&D products include:

Chlorine and iodine compounds

Solutions of sodium hypochlorite (bleach) are very common. Chlorine dioxide gas can be used for full area treatment or in solution. Solutions of iodine with a solubilizing agent, called iodophors, are also used as disinfectants.

Oxygen compounds

Solutions of hydrogen peroxide and peroxyacetic (peracetic) acid can be used for disinfection or sterilization. Use of vaporized hydrogen peroxide (VHP) for disinfection or sterilization of large areas, such as full rooms or isolators, is widespread.

Alcohols

Two of the most commonly used alcohols are ethanol and isopropanol. Typically used in a dilution of 70%, these alcohols are disinfecting but not sterilizing, nor are they effective against spores.

Quaternary ammonium compounds

Preparations of quaternary ammonium compounds are disinfectants. There are several types and formulations commercially available, often provided together with a detergent for a combined cleaning and disinfecting step.

Phenols

Various preparations of phenolic compounds are commercially available. These may also be formulated with detergents for combination cleaning and disinfection.

Aldehydes

Solutions of glutaraldehyde or formaldehyde can be disinfecting or sterilizing. However, worker protection against potential toxicity and irritation must be carefully considered when using these agents, especially formaldehyde, which is a known human carcinogen. Gaseous fogging of formaldehyde for full room decontamination is practiced under very controlled circumstances.

A more extensive overview of antimicrobial agents can currently be found in the CDC's Guideline for disinfection and sterilization in healthcare facilities (2008).

Choice and use of cleaning and antimicrobial agents

Choice of cleaning and antimicrobial agents involves consideration of many factors, including material compatibility; type of surface; application method; number and type of organisms to be killed or controlled; amount and type of soil to be removed; and others. Another consideration is whether to perform the cleaning and disinfection processes independently, first using a cleaning product followed by use of the disinfectant or using a one-step product that is capable of performing both the cleaning and disinfection simultaneously. In all cases, follow the manufacturer's instructions for use, including appropriate dilution (if required), contact time, application method, rinsing and decontamination.

An excellent resource for assistance with selecting a suitable antimicrobial product is the US Environmental Protection Agency's (EPA) lists of registered disinfectants. Disinfectants are currently registered as pesticides with the EPA as required under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

EPA Lists of Registered Disinfectants

Registered disinfectant products are organized into lists based on claims of effectiveness against target biohazardous microorganisms. For example, List E covers "Antimicrobial Products Effective Against *Mycobacterium tuberculosis*, Human HIV-1 and Hepatitis B Virus" and List N addresses "Disinfectants for Use Against SARS-CoV-2." In particular, List N is user friendly with search capabilities that include EPA registration number, active ingredient (e.g., sodium hypochlorite, phenolic), use site (e.g., healthcare, institutional, residential), surface type (e.g., porous, nonporous) and contact time.

The EPA updates these registered disinfectant lists periodically to reflect label changes, cancellations and transfers of product registrations. Listed products may not make efficacy claims against these biohazardous microorganisms unless the EPA has reviewed data to support the claim and approved the claim on the label.

Cleaning protocols

Although C&D has come more into the forefront due to the COVID-19 pandemic, these practices have been in place for decades for healthcare environments and trauma scene cleanups. Similarly, in certain industrial and laboratory environments, C&D is common as a preventative measure for sanitary reasons or in response to microbial contamination identified through quality-driven environmental monitoring systems.

As stated previously, the focus of this document is to provide guidance on selecting protective apparel for the safe handling of chemical-based C&D products. Therefore, the discussion will focus on the cleaning and application methods associated with these products. In addition to the selection requirements for the C&D products being used, key factors to consider for the decision on which cleaning protocol to employ include the type of surfaces involved (porous, nonporous or both) and the size of the area being cleaned. A variety of manual and automated application methods are available to consider based on these factors.

Cleaning usually involves manual methods because there is a requirement to physically remove dirt and/or organic matter (e.g., blood) to increase the effectiveness of the disinfection process. Manual scrubbing, wiping and mopping are typical methods for nonporous surfaces. Subsequent disinfection using a product with demonstrated effectiveness for the biohazard(s) of concern usually will involve the same types of methods.

Cleaning porous materials is more of a challenge. For COVID-19 prevention, the CDC currently recommends laundering clothing, towels and linens at the warmest possible temperature. If possible, also launder drapes, rugs and carpet. If laundering is not possible, clean these porous surfaces with a detergent or other appropriate cleaner, followed by application of an EPA registered disinfectant, if needed.

CDC guidance for cleaning, disinfection & ventilation

In some cases, large areas may need disinfection where some type of automated method may be preferred, such as fogging, vaporizing or electrostatic spraying. These methods may be selected for situations where surfaces are hard to disinfect by hand or the space needs to be addressed quickly.

Once a cleaning protocol has been determined, factors impacting handling and use of the antimicrobial agents can be evaluated. Liquid cleaning agents may be received as concentrated solutions, which must be diluted prior to use, or as ready-to-use formulations. Required personal protective equipment (PPE) for handling concentrates may differ from what is required when using dilute solutions. Similarly, PPE may be different and more extensive for protocols using automated methods compared to manual ones.

The elimination or reduction of microorganisms to safe levels is very dependent on the time that an agent is in contact with the surface to be decontaminated. Surfaces must remain "wet" per the instructions for use and for the full contact time recommended by the manufacturer to be effective. Some cleaning chemicals and antimicrobial agents may require an additional rinsing step to remove any residue.

In addition to the CDC guidance, the American Industrial Hygiene Association (AIHA) has developed "Back to Work Safely™" guidelines related to the COVID-19 pandemic that includes guidance on C&D. These guidelines address a wide variety of workplace environments and are meant to offer specific, easy-to-follow, science-based recommendations for limiting the transmission of the coronavirus.

OSHA guidance on mitigating and preventing the spread of COVID-19 in the workplace

CDC guideline for disinfection and sterilization in healthcare facilities (2008)

AIHA_personal protective equipment for SARS-CoV-2-guidance document (2020)

Hazard risk assessment and PPE selection

As part of planning for a C&D task, a hazard risk assessment should be completed to evaluate the need for worker protection, including protective apparel. Safety data sheets, labels, technical data sheets, instructions for use and other information provided by the manufacturers of the cleaning and antimicrobial agents can be useful sources of information.

Consideration needs to be given to the biohazard present in order to prevent infection and any resultant illness. Additionally, C&D agents tend to be irritating or corrosive to skin, eyes and the respiratory system, in particular in their concentrated forms.

In addition to the nature of the target biohazard and toxicity/safety profile of the cleaning or antimicrobial agents, other risk factors to consider are the potential for slippery surfaces, tripping hazards and ergonomics when cleaning in tight places, such as behind equipment or reaching for tops of shelves.

Appropriate eye, face, head and hand protection may be needed for the cleaning of ceilings and tops of walls if there is potential for dripping or exposure from overhead. Evaluation of different sole material on shoe covers that may have additional slip resistance, or additional accessories such as aprons or sleeves may also be required. If an inhalation risk exists, then respiratory protection also may be needed.

For C&D applications involving controlled environments, PPE properties such as garment cleanliness, particle shedding, filtration efficiency or other barrier properties may need to be evaluated. For aseptic cleanroom environments, sterile garments and accessories may be required.

DuPont Personal Protection has a Certified Industrial Hygienist team available to assist organizations with these complex decisions.

For up-to-date C&D chemical permeation data for DuPont™ Tychem® and select DuPont™ Tyvek® products, please refer to SafeSPEC™ (safespec.dupont.com), DuPont Personal Protection's comprehensive database of thousands of chemical permeation test results.

Planning for a C&D task must include a hazard risk assessment to evaluate the need for worker protection, including protective apparel. Additionally, the risk assessment will assist in determining the appropriate garments to be worn, including the design, fabric and seam of the protective apparel.

What protective apparel is available?

An important part of any cleaning protocol is protecting the workers who may be exposed during any step of the process. These processes vary widely not only in the cleaning/microbial agents that they utilize but also in the exposure scenarios the workers are subject to based on the cleaning protocol being utilized. The hazards might be related to skin contact, respiratory, eye protection or even something as common as slips, trips and falls. Due to the breadth of the hazards that must be considered, there is no one garment solution for all cleaning applications. Instead, a specific hazard assessment should be conducted to understand all potential scenarios and protect employees effectively.

The CDC, US Occupational Safety and Health Administration (OSHA) and World Health Organization (WHO) provide direction on infection prevention and control procedures related to SARS-CoV-2, MERS-CoV and other biohazards, including guidance for the use of PPE for C&D. This guidance is continuously being updated for emerging pathogens.

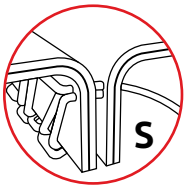
Garment selection criteria

When evaluating garments in relation to your specific risks and hazards, three important elements to consider are fabric, seams and design.

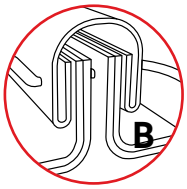
Fabric
Key fabric selection criteria include:

- Protection—Will potentially hazardous material penetrate or permeate through the garment? Does it comply with industry and/or government requirements?
- Durability—Will it maintain its protection throughout the task? Will change-outs be required during the task?
- Comfort—Will the garment contribute to heat stress? Will wearing the garment lower worker productivity?

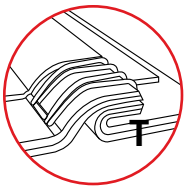
Seams
Seams can help provide garment strength, durability and hazard protection; however, an inappropriate seam construction can potentially compromise the barrier protection on a garment. There are five main types of seam construction:



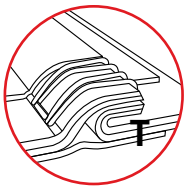
Serged (Sewn)
A seam is produced when threads are interlocked around the edges of two pieces of fabric.



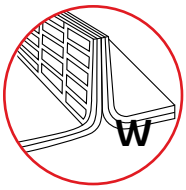
Bound
An outer binding is added to a tightly sewn seam to increase seam strength and improve seam barrier.



Taped
A strip of compatible material over a sewn seam increases strength and improves barrier protection against heavy liquid splash.



Double Taped
A strip of compatible material covers both the inside and outside surface of a sewn seam.



Welded
A seam is created by fusing two pieces of material ultrasonically or thermally.

Design
Garment design features are linked to the exposure scenario and end-user needs. The hazard risk assessment will help determine the appropriate PPE accessories and styles that should be used (e.g., coveralls, gowns, lab coats, hoods, sleeves, shoe covers).

DuPont Personal Protection—fabric solutions

Tyvek® 400
Tyvek® 400 garments are composed of flashspun high-density polyethylene which creates a unique, nonwoven material available only from DuPont. Tyvek® 400 provides an ideal balance of protection, durability and comfort of any limited use fabric technology. Tyvek® 400 fabric offers an inherent barrier against particles (down to 1.0 micron in size). Protection is built into the fabric itself; there are no films or laminates to abrade or wear away. Tyvek® 400 fabric's durability advantage over microporous film fabrics delivers consistently better barrier, even after wear and abrasion.

Tyvek® 600 and Tyvek® 800
Tyvek® 600 and Tyvek® 800 garments help bridge the gap between our general protection and chemical protection offerings. Tyvek® 600 provides a chemical permeation barrier to low concentration water-based inorganic chemicals. Tyvek® 800 provides an even higher level of protection by adding a protective film to the Tyvek® fabric. Both of these garments feature taped seams and other design features, such as respirator fit hood, storm flap with adhesive, and thumb loops, that contribute to the protection of the wearer. Tyvek® 600 and Tyvek® 800 garments provide protection against infective agents (EN 14126), including resistance to penetration by blood and body fluids using synthetic blood (ISO 16603). Tyvek® 800 garments also provide resistance to penetration by bloodborne pathogens using Phi-X174 bacteriophage (ISO 16604).

Tyvek® IsoClean®
Tyvek® IsoClean® clean-processed and sterile single-use garments are designed for cleanroom and other controlled environment settings. Tyvek® IsoClean® garments are available sterile and non-sterile in a wide variety of styles, such as coveralls, frocks, lab coats, hoods, gowns, bouffants, shoe and boot covers and sleeve protectors. Clean-processed garments offer the lowest shedding garments in the DuPont Controlled Environments portfolio. Sterile garments are gamma-irradiated to a Sterility Assurance Level (SAL) of 10^{-6} and are fully traceable.

Tyvek® 400 D
Tyvek® 400 D garments combine the protection, durability and comfort of Tyvek® fabric on the front and the comfort, softness and breathability of DuPont™ ProShield® 10 fabric on the back. Tyvek® 400 D garments are suitable for applications where comfort requirements are combined with limited protective requirements for frontal exposures.

ProShield® 50, ProShield® 60 and ProClean®
ProShield® 50 and ProShield® 60 microporous film garments are lightweight and suitable for protection against non-hazardous particles, light liquid splash and aerosols. Available in a variety of garment styles, they make an economical choice for C&D applications.

DuPont™ ProClean® is a microporous composite fabric that is used to produce apparel intended for use in a controlled environment, while providing non-hazardous liquid and dry particulate barrier.

ProShield® 70
ProShield® 70 shoe covers and boot covers are composed of a spunbonded polypropylene substrate that is coated with a low-density polyethylene film for enhanced skid resistance and barrier performance. ProShield® 70 fabric meets the US industry requirements for blood (ASTM F1670) and viral penetration (ASTM F1671), protecting against several bloodborne pathogen exposure risks.

Tychem® 2000 and Tychem® 4000
Tychem® 2000 provides excellent resistance against biohazards such as blood, body fluid and viral contaminants, and passes ASTM F1670 for blood penetration and ASTM F1671 for viral penetration. Tychem® 2000 disposable coveralls and long-sleeved aprons provide protection in pandemic preparedness activities against SARS-CoV-2 when paired with appropriate masks, gloves and eye protection. A comfortable, lightweight and durable fabric, Tychem® 2000 utilizes the strength of Tyvek® fabric and a polyethylene coating, making this one of the more comfortable and protective garments available. Tychem® 2000 fabric provides at least 30 minutes of protection against more than 40 chemical challenges.

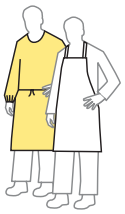
Tychem® 2000 Tape keeps your PPE in place while providing the same level of chemical resistance as Tychem® 2000 garments. The elasticity of the tape allows for tight adhesion to help prevent potential leak sources. The tape tears easily for quick application and its flexibility and adhesive allow for easy repositioning.

Tychem® 4000 utilizes chemical barrier film laminated to Tyvek® fabric to provide a rugged and durable fabric that resists abrasion. Tychem® 4000 fabric provides at least 30 minutes of protection against more than 124 chemical challenges.

Permeation results for all Tychem® products and select Tyvek® products are available at SafeSPEC™, including test results for common cleaning agents such as sodium hypochlorite (bleach), hydrogen peroxide and citric acid.

Protective apparel design choices

Coveralls
Coveralls are the optimal design choice when the potential exposure to cleaning agents and/or biological hazards could come from any direction. Although additional PPE may be needed, coveralls provide nearly full body coverage, often with options of an attached hood and/or attached boot covers. Coveralls may be worn while performing certain activities, such as automated spraying, manual cleaning and mopping.



Gowns and aprons
Gowns and aprons provide coverage of the upper body and generally fasten in the back of the garment, allowing for a higher level of protection for the front part of the body. Gowns and aprons may be good design options when the risk of exposure is primarily to the front torso of the worker.

Lab coats and frocks
Similar to gowns and aprons, lab coats and frocks provide protection to the upper half of the body; however, because they usually secure in the front, their protection level may not be ideal for certain applications where the risk of exposure is primarily to the front of the body. Easy to don and doff, lab coats and frocks may be suitable for situations where the risk of exposure is low.

Shirts and pants
Standalone shirts and pants allow more flexibility than a traditional coverall. The individual offerings allow for protection of the upper half of the body, the lower half of the body or both. While potentially easier to don and doff than a coverall, standalone shirts and pants will not provide the same level of protection as a one-piece coverall.

Sleeves
Standalone sleeves are practical when used in conjunction with a protective glove and when the exposure risk is limited to the hand and arm. Lighter cleaning applications, such as routine wiping of surfaces of low- or nonhazardous areas may only require the use of minimal protection, such as a sleeve.

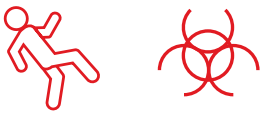
Shoe and boot covers
Shoe and boot covers provide a layer of protection to the feet and possibly ankles and lower legs. They can be used in conjunction with any of the other protective apparel designs. In addition to barrier protection, shoe and boot covers can also provide slip resistance, depending on the sole material. Slips can happen when a person loses their balance due to a loss of friction between their feet and the surface they're walking on. DuPont Personal Protection offers a variety of shoe covers and boot covers with varying degrees of skid resistance.

Protective tape
Chemical protective tape can help keep your PPE in place while providing a level of chemical resistance.

Automated cleaning

Manual cleaning

Mopping



This infographic focuses only on protective apparel. Additional PPE (including eye, respiratory and hand protection) may be necessary for these activities.

NOTE: Refer to SafeSPEC™ for a full list of garments that have been tested and have passed the requirements of ASTM F1670 and ASTM F1671 or ISO 16603:2004 and ISO 16604:2004 blood and viral penetration test methods. Although certain DuPont protective garments have passed the recognized ASTM or international test methods, they have not been tested against specific coronaviruses. Continue to consult the CDC for guidance on suitable PPE for protection from coronaviruses and other biohazardous agents.

ASTM F1670 – Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Synthetic Blood

ASTM F1671 – Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Blood-borne Pathogens Using Phi-X174 Bacteriophage Penetration

ISO 16603:2004 Clothing for protection against contact with blood and body fluids — Determination of the resistance of protective clothing materials to penetration by blood and body fluids — Test method using synthetic blood

ISO 16604:2004 Clothing for protection against contact with blood and body fluids — Determination of resistance of protective clothing materials to penetration by blood-borne pathogens — Test method using Phi-X 174 bacteriophage

	ProShield® 50	ProShield® 60	ProClean®	ProShield® 70	Tyvek® 400 D	Tyvek® 400	Tyvek® IsoClean®	Tyvek® 600	Tyvek® 800	Tychem® 2000	Tychem® 4000
Coverall	●	●	●		●	●	●	●	●	●	●
Gown							●				
Sleeved apron										●	●
Bib style apron	●	●				●				●	●
Lab coat		●				●	●				
Frock			●			●	●				
Shirt						●					
Pants					●	●					
Sleeves	●	●				●	●			●	
Shoe covers				●		●	●				
Boot covers		●	●	●		●	●				

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