Got Gas? Chlorine Dioxide or Vaporized Hydrogen Peroxide: Which one is right for you?

Megan Sawyer, Joy Pierzynski, and Megan Trapp

Biosecurity Research Institute, Kansas State University, Manhattan, KS

ABSTRACT

While the concept of gas decontamination is virtually identical among the different methods available, there are several options to consider when selecting the optimum method to use for a biocontainment facility. The Biosecurity Research Institute at Kansas State University in Manhattan, KS has the capability to use both vaporized hydrogen peroxide (VHP) and chlorine dioxide (CD) gas for decontamination. Comparative tests have determined that both methods can be used effectively throughout our facility, but the choice may be affected by the structural differences between BSL-3 and BSL-3Ag areas. The purpose of this poster is to compare and discuss both methods, CD gas and VHP, to identify the key procedural differences, to give a better understanding of both sterilants and raise awareness of the strengths and weaknesses of each method based upon the BRI's experiences.

OBJECTIVES

- Discuss and give background information about CD gas and VHP.
- Identify the differences between CD gas and VHP for room set-up and cycle development.
- Describe how and why each technology is used in the unique spaces of the BRI facility.
- Discuss the advantages and disadvantages of each method based on experiences in the BRI facility.

INTRODUCTION

Hydrogen peroxide is a colorless and odorless liquid at room temperatures. It is an oxidizer that can cause severe burns if it contacts the skin at high concentrations. It is considered environmentally friendly because it breaks down into oxygen and water. The 35% hydrogen peroxide solution (Vaprox®) used in the Steris VHP 1000-ARD System is concentrated at 35% and has a shelf life of 1 year for an unopened cartridge and 45 days for an opened cartridge. Cartridges come in 950 ml bottles or a 5 gallon drum.

The dry, vapor VHP decontamination process consists of four phases:

1. Dehumidification: humidity is removed from the room through an integrated desiccant system.
2. Conditioning: Vaprox® is vaporized and injected by generator into room to quickly raise the level of VHP to effective concentration.
3. Decontaminate: VHP concentrations are maintained by continually injecting VHP into room to provide an effective kill of microorganisms.
4. Aeration: Injection of VHP stops; supply and exhaust air is used to clear the room of VHP.

Figure 1. Steris VHP 1000-ARD System with dryer unit and dryer regeneration unit.

Chlorine dioxide gas is a yellow-green gas with a chlorine-like odor. It is an unstable oxidizer and therefore must be generated on site or *in-situ*. The ClorDiSys Minidox-M generator used at the BRI generates CD gas by starting with a gas instead of a liquid, which is different from how most other generators work. CD gas is safe for the environment and is used in water treatment, as a bleaching agent, the food industry, BSCs, etc. The chlorine gas tanks and the cartridges have a shelf life of one year. The chemical process of generating CD gas is:

$$Cl_{2(g)} + 2NaClO_{2(s)} \rightarrow 2ClO_{2(g)} + 2NaCl_{(s)}$$

A low level of chlorine gas (2% in nitrogen) is passed through cartridges containing sodium chlorite, which converts the Cl molecule to ClO_2. This allows the ClorDiSys generator to produce pure CD gas without the byproducts that are usually found in liquid solutions of CD. At the end of the process, sodium chlorite and sodium chloride are left in the cartridges.

The CD gas decontamination process consists of five steps:

1. Pre-Condition: humidity is raised to 65%.
2. Condition: the room is held at 65% relative humidity (RH) for 20 minutes to allow the spores on the biological indicators (BI) to swell and crack, allowing the sterilant to penetrate them.
3. Charge: CD gas is injected to the target concentration, which varies depending on room volume.
4. Exposure: CD concentration is maintained for appropriate contact time.
5. Aeration: CD gas is removed using supply and exhaust air.

Figure 2. ClorDiSys Minidox-M Decontamination Unit and external blower set-up.

MATERIALS AND METHODS

Table 1. CD materials and costs.

Chlorine Dioxide	Cost
Minidox-M Generator	$77,000
Chlorine gas tank	$378
Cartridge set for gas conversion	$750
Gas monitor	$1500
Biological Indicators (BI)	$150/box
Media	$100/box
Chemical Indicators (CI)	$100/box

Table 2. VHP materials and costs.

Vaporized Hydrogen Peroxide	Cost
VHP 1000-ARD System	$58,000
Vaprox® 5 gallons	$630
VHP Monitor (2)	$1100
Biological Indicators (BI)	$178/box
Media	$100/box
Chemical Indicators (CI)	$80/box
Maintenance	3 options

CD gas and VHP are delivered to a room in a closed-loop system as shown in Figure 3. Both sterilants are delivered to the room via decontamination ports installed in the supply and exhaust duct work (Figure 4A and 4B). Air is circulated in the room with oscillating or stationary fans (Figure 5A and 5B). *B. atrophaeus* (CD) and *G. stearothermophilus* (VHP) BIs and agent-specific CIs are hung in pairs throughout the room using easily removable blue painter's tape (Figure 6A and 6B). The BI/CI pairs are put in predetermined spots in each room and in any hard-to-reach places or under equipment (Figure 7A and 7B).

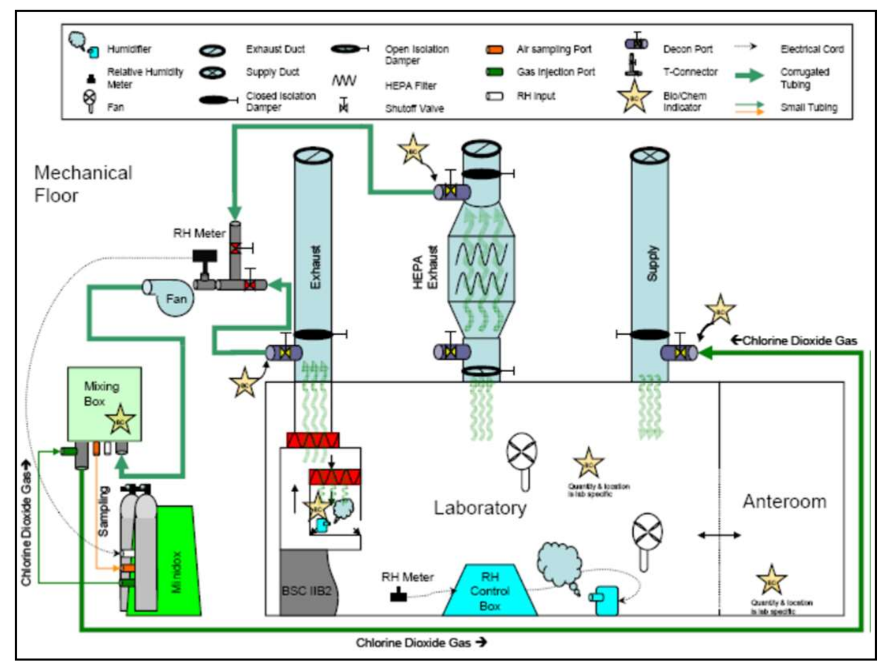

Figure 3. Closed loop system used at BRI (CD gas set-up shown).

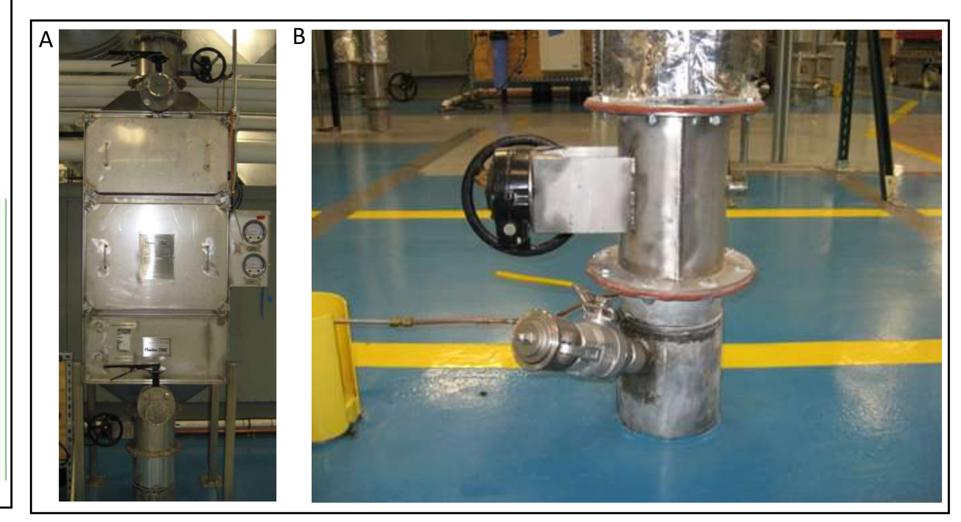

Figure 4. Decontamination ports on room exhaust HEPA filter housing (A) and room supply air (B).

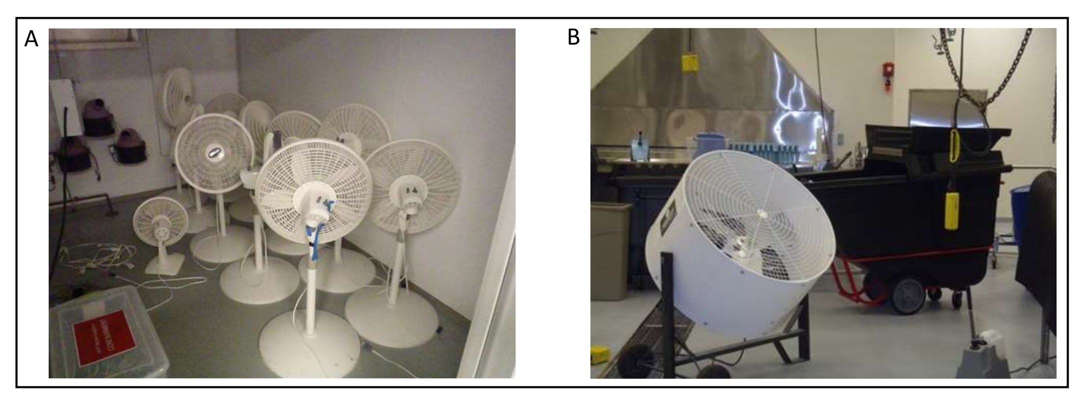

Figure 5. Oscillating fans (A) and large stationary fans (B) used at BRI during gas decontamination.

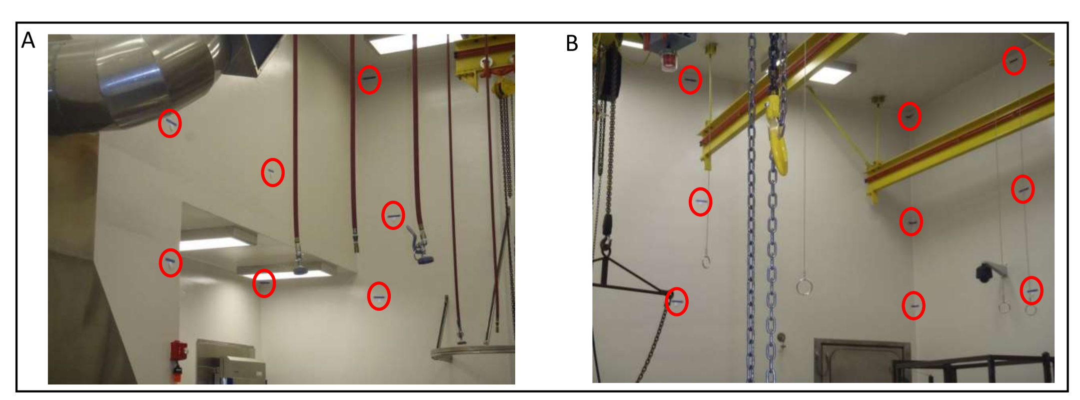

Figure 6. Biological (BI) and chemical (CI) indicator pairs hung throughout the room with blue painter's tape. During cycle optimization, BI and CI pairs are hung in predetermined spots throughout the room and in any hard-to-reach places .

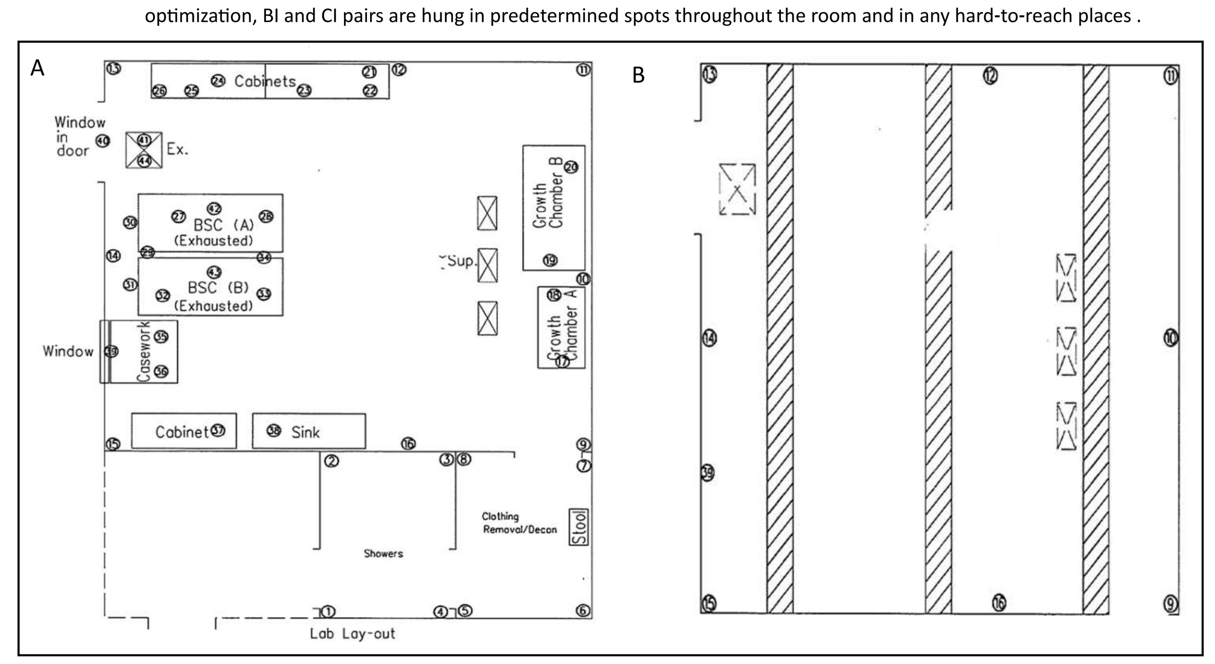

Figure 7. Typical room schematic of BI and CI placement in a BSL-3 lab during cycle optimization. The figure on the left shows BI and CI placement in the room (A). The figure on the right shows BI and CI placement above the false ceiling (B).

CONCLUSIONS

VHP (EPA Reg. No. 58779-4) and CD gas (EPA Reg. No. 80802-1) are registered with the US-EPA as sterilants, meaning they are effective against all forms of microbial life including: fungi, viruses, and all forms of bacteria and their spores. There are relative advantages and disadvantages for each technology, which are described below. Table 3 summarizes some of the attributes of each technology.

VHP Notes/Limitations

During cycle development and optimization trials using VHP, we determined that VHP would be used for our smaller BSL-3 lab spaces (< 5000 ft^3 or 141 m^3) due to the limitation of vapor distribution and long cycle times. It was difficult in larger spaces to maintain and distribute a high enough VHP concentration to achieve a successful cycle (100% BI kill rate). VHP was also not well-suited for larger spaces because of the size and capacity of the dryer cartridge. Without being able to use the in-house ventilation system to adjust the room RH to an acceptable level, the amount of humidity the dryer cartridge can hold limits the volume of the room that can be decontaminated. It was also observed that VHP caused damage to the epoxy floors in the BSL-3Ag spaces. During one trial in a BSL-3Ag space, excessive VHP condensation on a cold air supply register resulted in liquid hydrogen peroxide dripping and puddling on the epoxy floor, which resulted in costly repairs.

A significant number of fans were found to be required for successful VHP cycles to ensure the vapor is moved throughout the room, accessing every corner or hard-to-reach spot. Fan placement was recorded on room schematics and fans were set up the exact same way every time that a cycle was run to ensure the cycle would be successful.

VHP aeration times tended to be overnight because any porous material in the room can absorb the VHP and "off-gas". Depending on the room content (laboratory supplies, equipment, etc.), the aeration phase sometimes exceeded the typical overnight timeframe.

Cycle development was our most significant difficulty when working with VHP. Depending on room construction and configuration, it was necessary to adjust exposure times and typically extended those times beyond the manufacturer's recommendations in order to achieve successful BI kill rates.

CD Notes/Limitations

Manufacturer's specifications state that CD gas can be used on spaces up to 70,000 ft^3 or 1982 m^3. This was tested during cycle optimization on the large BSL-3Ag spaces (5,000-10,000 ft^3 or 141-283 m^3) and on the Necropsy floor (40,000 ft^3 or 1133 m^3). These large spaces were successfully and repeatedly decontaminated using CD gas, making it the preferred decontamination method for large spaces at the BRI. Several trials were run with the smaller BSL-3 lab spaces and it was found that CD gas also works well to decontaminate these rooms, but continual monitoring of the space and surrounding area is required. Continual monitoring is necessary in these spaces because CD is a true gas, so it is able to penetrate everywhere. It was discovered that CD gas sometimes penetrated into adjacent more negative spaces through the electrical outlets, phone and data outlets, and pressure and fire alarm panels. This occurred when the room being gassed was in a neutral air state and the adjacent spaces were negative. The outlets and panels were able to be easily sealed with heavy duty duct tape. When the adjacent BSL-3 spaces were also placed in a neutral air state, the negative pressure on the room being decontaminated was alleviated, and so the amount of CD gas being pulled into the adjacent BSL-3 spaces was minimized.

Required air circulation was much lower for CD gas compared with VHP, necessitating only a few fans to move the gas throughout the entire room. In the very large Necropsy space, two large stationary fans along with several oscillating fans were used to distribute the CD gas (Fig. 5). The RH was manually controlled to 65-70% using several small steam injectors (as recommended by ClorDiSys).

Aeration tends to be relatively fast with CD gas, with room re-entry being safe in approximately 30-60 minutes depending on room size. It was noted, that the room had a slight bleach-like odor after CD decontamination. This is due to the absorption of the gas into plastic and other materials in the room. Using a low level CD gas sensor, no measureable residual gas remained in the room despite the odor, so safety was not a concern. After 24-48 hours, the bleach-like smell dissipates.

Some corrosion was noticed in the Necropsy space on the overhead crane system, on metal equipment other than stainless steel or coated metal, and on certain welds. During the planning phase of construction, use of CD gas was not considered; therefore more corrosion may be occurring in the BRI facility than what would typically occur in a facility that was designed and constructed with the intent to use CD gas. The corrosion that occurred on the ferrous material in the BRI facility was able to be removed by a thorough cleaning with Wonder Gel (pickling gel recommended by ClorDiSys) and as of yet, the metal appears to be protected from further corrosion.

Table 3. Summary of CD gas and VHP attributes.

	Chlorine Dioxide gas	Vaporized Hydrogen Peroxide
Odor Detection	Yes	No
Cycle Time	3-4 hours	Depends on size of space
Vent to Environment	Yes	Yes
Penetration and Distribution	Yes	No
Penetrate Water	Yes	No
Equipment Location	Outside Room	Inside or Outside Room
Generator max volume (manufacturer's specifications)	Up to 70,000 ft^3 (1982 m^3)	Up to 10,000 ft^3 (283 m^3)
RH Requirement	High—65%	Low—10-70%
Cycle Development	No	Yes
Air Movement	Minimal	High
Aeration Time	30-60 mins	Overnight
Carcinogen	No—ACGIH No—OSHA	Yes—ACGIH No—OSHA
Integrated Concentration Monitoring	Yes	No