PENETRATION OF CHLORINE DIOXIDE GAS INTO MULTIPLE SURFACE ORGANIC LOADS

BRETT COLE, CAMERON WELCH, ALLAN HECKENBERG
BIOSAFETY INTERNATIONAL

Introduction

One of the most significant risks of a containment breach is servicing critical items used in PC3/4 laboratory environments. Filtration systems, cabinets, equipment, and waste systems that require maintenance – demand complete decontamination for staff safety, the duty of care and containment purposes.

To assure this level of decontamination safety, one must consider a specific attribute of sterilant materials: the achievement of sufficient exposure – the combination of time and concentration - under the appropriate environmental conditions. To achieve effective sterilisation, the sterilant has to reach the intended target.

Exposure Time and Contact is Critical

Several common contaminants can impede that contact, biofilm, thick layers of dust and debris, and densely packed surfaces (such as filters or packaging). This study explores several of these challenges, where chlorine dioxide gas had to penetrate difficult-to-reach surfaces and proposes some reasons why the gas can move through contaminant load effectively.

Background on Gas

IInherent in the use of chlorine dioxide gas as a sterilant, is that it is a gas, obeying the chemical and physical laws of gases. Other studies have detailed the reasoning behind the very high sterilisation efficacy and the low levels of chemical damage to vulnerable laboratory surfaces, in this work we focus on the movement of the gas to reach target pathogens.

Some gases are extremely good at penetrating surfaces and finding leaks – Helium has is commonly used to test solid metal pipes, to find virtually invisible leaks. Similarly, Chlorine dioxide is regarded as a "slippery gas", it has a surprising ability to rapidly penetrate semi-permeable surfaces (packaging, dense HEPA filters etc). Review of table 1., suggests the likely reason for this, with relatively high values for gas penetrations of materials.

Permeability (*P*), Diffusion (*D*), and Solubility (*S*) Coefficients of 10 Mg ClO_2 /L ClO_2 Gas (3600 ppmV) for Selected Polymers at 23°C

Polymer	$P \times 10^{-17}$ $\left(\frac{kgClO_2 \cdot m}{m^2 \cdot s \cdot Pa}\right)$	$D \times 10^{-14}$ $\left(\frac{m^2}{s}\right)$	$S \times 10^{-3}$ $\left(\frac{kg}{m^3 \cdot Pa}\right)$
HDPE	24.1 ± 0.42^{a1}	$3.14 \pm 0.06^{a,e}$	7.68 ± 0.27^{a}
LDPE	66.0 ± 1.09^{b}	26.2 ± 5.11^{b}	$2.59 \pm 0.46^{b,g}$
LLDPE	96.8 ± 1.34^{c}	40.4 ± 2.40^{c}	$2.40 \pm 0.17^{c,g}$
PS	41.8 ± 0.82^{e}	9.15 ± 0.47^{d}	4.57 ± 0.02^{d}
PVC	23.5 ± 0.46^{a}	$7.65 \pm 0.96^{d,e}$	$3.11 \pm 0.38^{b,f}$
PET	1.26 ± 0.03^{f}	0.32 ± 0.02^{a}	3.92 ± 0.19^{e}
PLA	5.40 ± 0.13^{g}	2.86 ± 0.18^{a}	1.90 ± 0.15^{c}
BOPP	3.04 ± 0.16^{d}	0.39 ± 0.02^{a}	7.84 ± 0.17^{a}
Nylon	$1.80 \pm 0.07^{d,f}$	0.53 ± 0.02^{a}	$3.43 \pm 0.18^{e,f}$

Table 1. Permeability factors.

Given these values, it is not surprising that the gas it will diffuse swiftly to fill a cavity, contacting all available surfaces and demonstrating excellent penetration of surface films such as; dust, debris and oils/biofilms, certainly passing through filter surfaces (like dense HEPAs) with ease – unlike any non-gaseous, or vapour phase chemical.

Methods

The generalised Chlorine Dioxide, gas decontamination process consists of:
a) Humidification to a suitable target %RH, an optimal 65 - 75% level.
b) Introduction of chlorine dioxide (CD) gas to reach the desired concentration, between 1-5mg/m3.
c) A dwell period for exposure that is well above the target pathogen sterilisation of 720 ppmhours.
d) Aeration to remove the gas to 0.1 ppm, 8-hour exposure safety and odour threshold level (Safe Work Australia, 2019).
e) Confirmation of the sterilisation success with biological indicators or other validation means.

Gas is generated in situ to be dry and pure with ClorDiSys Gas generation cartridges that have controlled rates/pressures of pure compressed 98 % Nitrogen with 2% Chlorine Gas. Concentration and exposure values are collected using an Opitek fixed wavelength single beam photometer with an integrating software device (EMS ClorDiSys). Biological indicators are task-specific, frequently 10^6—stearothermophilus loaded strips, developed in modified tryptic soy digest broth.

Case Studies

Two informative case studies explore challenging cases of achieving contact/exposure with high pathogen level risks: a PC4 EDS liquid waste decontamination system and an exhaust ventilation HEPA housing system.

PC3/4 EDS Systems Decontamination

Full decontamination was required maintenance on a storage tank for the EDS system. Steam sterilisation has significant hazards and difficulties in practical implementation; liquid disinfection is impractical from effectiveness, waste volume, cost and down-time perspectives. Sterilisation involves moving gas into the chamber through a HEPA vent isolation filter, then venting through another. The ability for the gas to penetrate through these comparatively small HEPA filters without causing excessive pressure drop (and subsequent damage) allowed the 3000L plus tank to be effectively filled to very high concentration 5mg/L levels, held for the required exposure time, and then safely vented to a carbon scrubber led to an effective sanitisation of the vessel and all wetted surfaces.

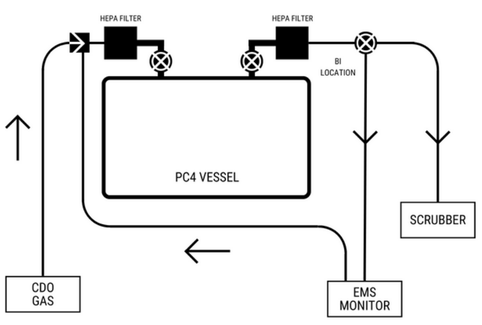

Figure 1. disinfection gas flow through HEPA vent filters.

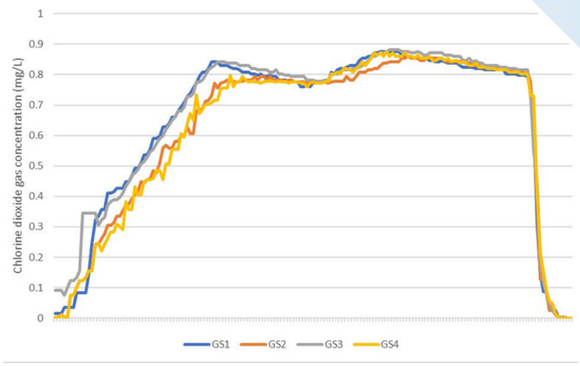

Figure 2. Generic exposure over time showing target exposure reached.

Results

The excellent permeation ability of chlorine dioxide gas allowed passage through relatively low flow/delicate HEPA vent filters to effectively and swiftly fill a very large pressure vessel. The whole task could be safely achieved within one half-day, allowing adequate maintenance time, then a return to the operation within the day (according to satisfactory BI results).

PC3 Ventilation Exhaust HEPA Filter Housing

Part of any PC3/4 laboratory ventilation system is the placement of high-volume HEPA filters to preclude breaches of containment from exhausted pathogens. These filters require regular changeouts when the filter pressure drop rises to above-specified levels – primarily due to particulate contamination build-up.

Figure 3. 4mm of dust covering BI, showing dust and debris penetration of chlorine dioxide gas.

The entire filter requires sterilisation before it can be accessed and removed; similarly, the housing – up and downstream requires sterilisation. This is partially due to the precautions against possible filter breakthroughs. The sterilant agent must contact both sides of the filter and all internal surfaces of the housing. Additionally, it is wise to have the porous surfaces and seals of the HEPA penetrated with sterilant, dust and debris build up on filters must also be penetrated. An example of 4mm dust penetration is shown in figure 4.

Commonly HEPA containment units are configured to allow the safe passage of sterilant in and out of the unit. Access connections, protected by gas-tight valves, one up and one downstream of the filter, allow passage of gas into and out of the unit. As these systems are designed for airflow – effective distribution of the sterilant gas can be aided by placing a side channel blower into the gassing loop, circulating the sterilant gas continually. In common with regular practice, biological indicators are used to confirm sterilisation. In most cases, assessment with an exposure monitor (EMS) is also done on the first sterilisation of the unit. Subsequent gassing can be done by following the same conditions and processes, confident that the settings are sound.

Figure 4. HEPA filter housing and gas flow through the system for sterilization.

Results

Chlorine dioxide sterilant application has unique benefits to HEPA housing decontamination. The gas can effectively penetrate the filter itself through the filter particulate load and gives good depth penetration into soft seal surfaces. If coordinated with the filter change process, the downtime for these critical maintenance procedures is sharply reduced, allowing labs to be up and running as soon as possible, confident that the process protects from beaches and risk to staff.

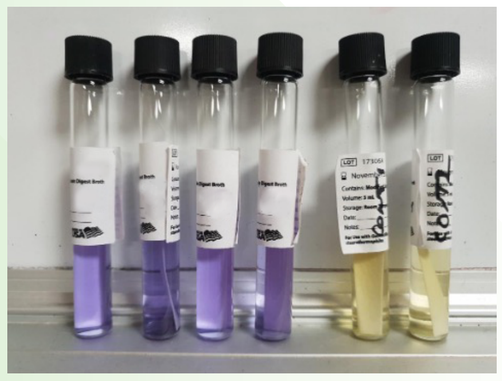

Figure 5. Biological indicator indicating successful HEPA decontamination. Control, yellow show growth, purple vials show successful decontamination.

Conclusions

Due to the natural properties of a true gas, challenging sterilisation situations can be effectively and safely concluded. The high efficacy of chlorine dioxide as an effective sterilant, combined with the ability to penetrate permeable and soft materials with little or no damage to the fundamental material, makes it an invaluable tool in decontamination for biological pathogens.

References

Bhagat A, Mahmoud BS, Linton RH. 2010. Inactivation of Salmonella enterica and Listeria monocytogenes inoculated on hydroponic tomatoes using chlorine dioxide gas. Foodborne Pathog Dis 7:677–685.

ClorDiSys Solutions. [Internet]. 2012. Biological efficacy of chlorine dioxide. [Cited 6 June 2013]. Available at: www.chlordisys. com/biological_efficacy.pdf

Czarneski MA. [Internet]. 2006. Gaseous chlorine dioxide and the myth of corrosion. [Cited 22 August 2013]. Available at: http:// www.clordisys.com/White_Paper_CD_and_the_myth_of_Corro- sion.pdf.

Czarneski MA, Lorcheim P. 2005. Isolator decontamination using chlorine dioxide gas. Pharma Tech 4:124–133.

Dix J, Astill J, Whelan G. 2004. Assessment of methods of destruction of Syphacia muris eggs. Lab Anim 38:11–16.

Han Y, Applegate B, Linton RH, Nelson PE. 2003. Decontamination of Bacillus thuringiensis spores on selected surfaces by chlorine dioxide gas. J Environ Health 66:16–21.

Hill WA, Randolph MM, Mandrell TD. 2009. Sensitivity of perianal tape impressions to diagnose pinworm (Syphacia spp.) infections in rats (Rattus norvegicus) and mice (Mus musculus). J Am Assoc Lab Anim Sci 48:378–380.

Huerkamp MJ, Benjamin KA, Zitzow LA, Pullium JK, Lloyd JK, Thompson WD, Webb SK, Lehner ND. 2000. Fenbendazole treatment without environmental decontamination eradicates Syphacia muris from all rats in a large, complex research institution. Contemp Top Lab Anim Sci 39:9–12.

Kuroyama I, Osato S, Nakajima S, Kubota R, Ogawa T. 2010. Environmental monitoring and bactericidal efficacy of chlorine dioxide gas in a dental office. Biocontrol Sci 15:103–109.

Lenntech. [Internet]. Disinfectants chlorine dioxide. [Cited 3 July 2013]. Available at: www.lenntech.com/processes/disinfection/chemical/disinfectants-chlorine -dioxide.htm#ixzz2VpvNJbjL

Li YJ, Zhu N, Jia HQ, Wu JH, Yi Y, Qi JC. 2012. Decontamination of Bacillus subtilis var. niger spores on selected surfaces by chlorine dioxide gas. J Zhejiang Univ Sci B 13:254–260.

Safework Australia 2019, Workplace Exposure Standards for Airborne Contaminants. Available at: https://www.safeworkaustralia.gov.au/doc/workplace-exposure-standards-airborne-contaminants-2019

BioSafety International

1300 379 996
info@biosafety.com.au
www.biosafety.com.au
Unit 15, 69 Acacia Road, Ferntree Gully, VIC 3156