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Vaporous & Gaseous Decontamination

Introduction

Decontamination is an important but often overlooked aspect of laboratory design and is of particular importance in high containment facilities. The term "decontamination" itself is often misused and misunderstood. As described by the BMBL, decontamination renders an area, device, item, or material safe to handle (i.e., safe in the context of being reasonably free from a risk of disease transmission). Additionally, decontamination covers a range of inactivation procedures, from the more severe, sterilization, to less severe, sanitization. Sterilization is categorical and absolute; after sterilization the probability of a microorganism surviving on an item's surface is less than one in one million.[1] Disinfection and sanitization are less lethal than sterilization and are often distinguished by their relative ineffectiveness against bacterial spores.[1] Whether decontamination of an area, device, or material is accomplished by sterilization, disinfection, or sanitization, the end goal is always worker and environmental safety. In order to achieve a successful decontamination one must select the appropriate process and agent for each situation, being aware of the potential drawbacks of the materials and methods used.

Considerations

An effective decontamination should have the following features:

1. Good and complete distribution of the sterilant or disinfectant
2. Good and total penetration of materials and surfaces
3. Sufficient contact time at specified concentrations[3]

An effective decontamination, achieving the above properties, can be accomplished with appropriate planning and consideration. Some of the more important concerns that may influence the efficacy of vaporous and gaseous decontamination are:

- The size and layout of the area(s) to be decontaminated
- The materials and equipment within the area to be decontaminated
- The nature and quantity of the contaminating microorganism(s)
- The amount of organic material present
- The ability to control the conditioning of the air (temperature, relative humidity, and pressure)

Methods

The most common vaporous and gaseous agents used for laboratory decontamination are: **formaldehyde gas, vaporous hydrogen peroxide, and gaseous chlorine dioxide**. Each of these methods varies in their efficacies in different environmental conditions, cost, ease of use, toxicity, and required exposure times. Careful thought should be given to each chemical agent prior to its use.

Formaldehyde Gas is the oldest method of gaseous decontamination and until recently the most prevalently used. Some benefits of formaldehyde gas are its ease of use, low relative corrosiveness, and even distribution across large volumes or irregular shapes. These benefits, though significant, need to be weighed against the shortcomings. One of the most significant drawbacks to formaldehyde is its toxicity. In 2006 the International Agency for Research on Cancer (IARC) classified formaldehyde as a known human carcinogen. Some additional drawbacks are formaldehyde's labor intensive cleanup process, the inability to monitor concentrations, the necessity for high relative humidity levels (between 70 – 90%), and its inability to penetrate soil loads and water.

Vaporous Hydrogen Peroxide (VHP) is one of the most frequently used agents for decontamination and it has been proven effective in a variety of scenarios. VHP can be used for the decontamination of a variety of organisms, including some bacterial spores.[2] Additional benefits of VHP include lower toxicity than other methods, as it readily breaks down into water and oxygen, easy cleanup process, and real time monitoring of VHP concentrations. Like other decontamination agents, VHP also has some distinct disadvantages. VHP has been shown to be incompatible with certain materials such as nylon, neoprene, certain anodized aluminum and some epoxides.[2] Other negative material interactions can occur with porous materials in which organisms embedded in cavities are not reached. Last, similar to formaldehyde, VHP's efficacy is greatly reduced by soil loads and water, pre-cleaning is required.

Gaseous Chlorine Dioxide (GCD) has been used to decontaminate in other industries for some time now; however, it has only recently begun to be used in high-containment and research facilities. Similar to hydrogen peroxide, chlorine dioxide functions as an oxidizing agent and is effective against a variety of organisms. An additional benefit to chlorine dioxide is that it is a particularly selective oxidizing agent, in that it only reacts with highly reduced molecules, severely limiting the impact of soil loads on its efficacy.[2] Some other benefits include relatively low cost, short contact times for decontamination, and the ability to monitor concentrations in real time. Again, similar to other decontamination methods, GCD also has shortcomings. Probably the most notable is that GCD is susceptible to decomposition from sunlight; window coverings are necessary for appropriate concentrations to be maintained. Further drawbacks include the necessity for high relative humidity (between 70 – 90%) and GCD's decreased efficacy when porous materials are involved.

Conclusion

Similar to other aspects of laboratory design and operations, there is no "one size fits all" solution for decontamination. Careful evaluation must be given to time, materials, costs, spaces, labor, and organisms involved. With appropriate planning and considerations, any of the discussed methods can provide an effective decontamination.

References & Resources:

[1.] Biosafety in Microbiological and Biomedical Laboratories, 5th Edition. 2009, Pp. 326 – 335.

[2.] Diane Gordon, Bree-Ann Carruthers, and Steven Theriault, "Gaseous Decontamination Methods in High-containment Laboratories" Journal of the American Biological Safety Association 17 (2012): 34.

[1.] Mark A. Czarneski, "Selecting the Right Chemical Agent for Decontamination of Rooms and Chambers" Journal of the American Biological Safety Association 12 (2007): 85.