Technews

National Dairy Development Board

For Efficient Dairying

Jan-March 2018 **Issue No. 94**

Fumigation-for decontamination

This bulletin includes technical information based on latest developments on products, systems, techniques etc. reported in journals, companies' leaflets and books and based on studies and experience. The technical information in different issues is on different areas of plant operation. It is hoped that the information contained herein will be useful to readers.

The theme of information in this issue is **"Fumigation-for decontamination"** It may be understood that the information given here is by no means complete.

In this issue:

INTRODUCTION

During manufacture, food can be exposed to microbiological cross contamination from surfaces, store/warehouses and air which may give rise to food spoilage and safety issues. The traditional approach to controlling such contamination has been to target specific sites within the manufacturing environment with cleaning and disinfection regimes. Food production equipment and its accessories are cleaned with predefined cleaning cycles, however much of the processing area is not feasible for routine decontamination.

Some of the research highlighted that presence of Listeria spp. and *Escherichia coli* that had remained in the high risk areas-chilled food factories-processing environment in excess of three years in spite of following operating good practice cleaning and disinfection regimes. Fumigation/ whole room decontamination approach may be good option to maintain day-to-day control of contamination.

Fumigation is action of releasing a chemical in the gaseous state to control a targeted microbial contamination. The most effective way to reach microbes in inaccessible places is through fumigation, using gases to kill in an enclosed area.

The goal of any fumigant introduction process should be to introduce the fumigant as quickly and efficiently as possible while not damaging any materials within the fumigated structure. For fumigants released from cylinders, the total amount of fumigant to be introduced and the delivery rate (kg/min) are factors to be considered in determining the number of shooting lines necessary to introduce the fumigant within the desired introduction

time. This *Technews* highlight the various methods and chemicals and its application in food industry.

Decontamination principle and need in food industry

Decontamination and disinfection protocols for biological agents vary significantly depending on the application. For example, requirements of the food industry are very different from those of paramedic services. No single disinfectant is adequate for all situations and disinfection protocols can differ based on the need, such as the containment of an infectious disease outbreak. The identity of the microorganism of concern and the chosen disinfectant both contribute to the effectiveness of decontamination, along with the conditions under which the procedure will be performed.

Food facilities typically manually wash as many surfaces as possible with an anti-microbial solution in an attempt to kill as many as possible contaminating microorganisms. The type of disinfectant used and the frequency of disinfection vary by facility. Some microorganisms typically survive the process either because the agent did not reach them at the proper concentration for the required contact time or because the microorganisms have developed mechanisms to cope with these cleaning agents and temperatures.

Biofilms occur widely and may become major problems in foods processing facilities. Terminal cleaning practices involve routine (e.g. monthly) thorough cleaning of a facility (including all surfaces and equipment). Some dry facilities do not perform terminal cleaning processes. If microorganisms are not being completely removed, they can slowly build up their population and spread over larger areas increasing the chances of contamination.

Key requirements of Fumigation process

Requirements of fumigation equipment and process can be summarized as follows:

- ✓ Flexibility: applicable for small and large rooms/ volumes (scalable).
- ✓ Minimal requirements as to environmental conditions (temperature, humidity)
- ✓ Quick install: either mobile or fix-installed equipment
- ✓ Safe use for personnel: non-hazardous, low toxicity
- ✓ Non-corrosive chemical, non-persistent
- ✓ Ease of clearing after fumigation, fast operability
- ✓ No residues, harmless byproducts from decomposition, no need for neutralization
- ✓ broad inactivation spectrum (bacteria, virus, yeast, molds)
- ✓ high inactivation rate (kill rate) and efficiency
- ✓ Process well understood (process knowledge: knowledge, design, and control).
- ✓ Simple and reliable qualification method for efficiency
- ✓ Validated process
- ✓ Fast and robust process
- ✓ Can run in parallel to normal work in adjacent rooms.

Decontamination Methods for Whole Rooms

The decontamination of enclosed environments is an important consideration for the control or remediation of pathogens and environmental contaminants in industrial facilities. Current room decontamination methods include (a) gaseous systems (b) vapor systems (both “wet” and

"dry" hydrogen peroxide), (c) misting and fogging systems (d) UV/Ionization, and (e) manual spray and wipe techniques that use a variety of liquid disinfecting or sterilizing agents. A wide variety of liquid-based detergents and disinfectants is currently employed, including alcohol, quaternary ammonium compound and phenol-based products. These formulations can vary considerably in their antimicrobial activity and are generally bactericidal, virucidal, and fungicidal, but many have limited to no activity against resistant microorganisms, including Mycobacterium species and bacterial spores. Alternative liquid-based formulations that demonstrate activity against these organisms include oxidizing agent and aldehyde-based formulations. The most widely used oxidizing agents include sodium hypochlorite ("bleach"), chlorine dioxide, hydrogen peroxide, peracetic acid, or combinations thereof (see table 1). Oxidizing agents are recommended due to their broad spectrum, general antimicrobial activity rendering less susceptibility to resistance acquisition, and desired environmental/safety profiles; for example, hydrogen peroxide (H_2O_2) breaks down into oxygen and water. Various methods and decontamination agents are discussed below in detail and summarized in table no 2.

Manual Spray and Wipe

Manual wiping involves hand spraying a high-level liquid disinfectant or foam on all surfaces, or wetting a mop/wipe and wiping surfaces to both physically remove organisms and apply a solution to kill organisms. The spraying/foaming method is more likely to reach all surfaces compared to the mop/wiping method since it achieves wider coverage. Benefits of this method are that the equipment and consumable costs are low. The disadvantages/shortcomings of this method are that it's

difficult to spray or wipe all surfaces of equipment including corners, crevices, undersides of ventilation grills and the inside of components. In addition, uniform coverage is extremely difficult to achieve, thus in the areas that get less coverage, the decontamination may not be as complete or effective.

When using the spray and wipe or mop method, respirators may be required to protect the user from harmful vapors, or off-gassing. Many liquid disinfectants are acidic or corrosive and require an additional step of rinsing with water to remove corrosive residue. If this step is not completed material corrosion can occur.

Spray and wipe techniques may be the appropriate method to use when spot decontamination is required. It may be the only method available if the in-room process cannot be shut down and the room evacuated, as is necessary for more thorough methods.

Table 1: Comparison of properties of gaseous decontamination agents

Disinfectant	Biocidal spectrum Activity in the presence of Organic	Speed of action	Chemical hazards	Chemical Compatibility	Environmental concern
Formaldehyde	+	±	±	+	+	±
Glutaraldehyde	+	±	+	+	+	±
Peracetic acid	±	±	+	nd	±	nd
H_2O_2	±	-	nd	+	±	-
Chlorine	+	+	+	+	±	+
Chlorine Dioxide	+	+	+	+	±	+

(+) property adequate for disinfection process; (±)mostly adequate but some limitations; (-) limitation or problematic property; (nd): not determined

Table 4: Summary of Decontamination Methods & Agents

Issue	Spray/wipe /mop	Fogging	Formaldehyde Gas	Hydrogen Peroxide Vapor	Chlorine Dioxide Gas
Equipment Cost	Low	Low	Low	Moderate-High[1]	Moderate
Labour Costs	High	High	High	Low	Low
Consumable Costs	Low	Low	Low	Low	Low
Facility Downtime Costs (cycle time costs)	High	High	High	Moderate	Low
Corrosiveness	Low - High (agent specific)	Low - High (agent specific)	Low	Low (Unless condensation)	Low
Total Cycle Time	1-2 days	1 - 2 days	9 - 15 hours + clean up	4 hours (small) 12 hours (large)	1.5 hours (small) 5 hours (large)
Residues	High	High	High	Low	Low
Concentration Monitoring	No	No	No	Yes (not all equipment have integrated monitoring)	Yes
Scalability	Yes	Yes	Yes	Yes[2]	Yes

[1]Moderate to high due to the equipment for multiple generators for some rooms.
[2]Scalability of these techniques is feasible but the expenditure to scale-up can become cost-prohibitive due to manpower and time required or equipment cost.

Automatic Fogging

Sprayers, foggers, atomizers, and misters are an improvement over the manual spray and wipe technique for entire rooms since the operator is removed from the process; however, it is still limited in its ability to reach all areas. The purpose is to create and disperse a disinfectant aerosol to reduce the numbers of airborne micro-organisms and also to apply disinfectant to surfaces that may be difficult to reach. Fogging is achieved using either a static, purpose-built system in a factory area with strategically placed nozzles or, more commonly, a mobile unit. The benefits of the automatic systems are that the human factor is removed from the process, but the human is involved in the placement of the equipment and, if it is not placed in the room correctly, then complete decontamination may not occur. Equipment costs are low compared to equipment costs for gaseous or vapor systems.

Applying chemical disinfectants to production areas as fogs or mists is a method that has been used routinely in the food industry to control cross contamination from microbial aerosols. Disinfectants that can be fogged in food processing environments include quaternary ammonium compounds, amphoteric and peracetic acid. For whole room disinfection, fogging is only effective if sufficient chemical is deposited onto all of the surfaces, but research has shown that the greatest effect is on the air and horizontal surfaces, with minimal effect on vertical surfaces and underneath equipment. The procedure can be improved with the use of electrostatic fogging nozzles, which help ensure a greater surface coverage of the aerosol droplets, even on non-horizontal surfaces. Chemical fogging can also be an issue if electrical items are located in the area being disinfected.

Foggers or misters typically take a high-level liquid disinfectant and spray a fine mist or very small droplets (5-100 microns) around the room. The equipment supersaturates the atmosphere with a disinfectant fog; the area covered will vary depending on the application system being used. A built-in system will typically be used for production areas >200m^3, with mobile units usually being employed for areas <200m^3, under typical conditions, fogging is carried out for a minimum of 15–30min to enable the fog to disperse and the chemical action to occur. After fogging, an additional period of 45–60min is required to allow the droplets to settle out of the air and onto the surfaces. Electrostatic charging of chemical fogs during aerosolisation can improve the application as the droplets will be attracted to surfaces that are electrically charged. While walls generally get good coverage, the underside or backside of components may remain inadequately covered, leaving areas that are not disinfected or decontaminated. Additionally, any equipment present in the room (racks, tables, or shelving) must be removed since the spray will not reach the backside, or underside of the equipment.

Furthermore, spraying in odd-shaped rooms does not get complete or even coverage since the spray does not reach all surfaces. One benefit for the foggers from a safety perspective is that the person is not in the room during the procedure, thereby eliminating human health concerns.

Gaseous systems

(i) Formaldehyde is a very effective method that has been used longer than all of the other "gassing" methods, and is very well understood. The main benefit of formaldehyde is that it is a gas. Gasses offer excellent distribution and penetration in to hard-to-reach areas, but are limited by their inability to penetrate soiled loads or bioburden. It is

effective against a broad range of organisms and is low in cost. The major concern with decontaminating rooms, buildings, and vessels with formaldehyde is that it is listed as a potential carcinogen by the U.S. EPA and as a human carcinogen by the International Agency for Research on Cancer (IARC) (IARC, 2004). While the permissible exposure level (PEL) for formaldehyde is 0.75 ppm, the classification of this agent as a carcinogen makes it extremely important to take care to avoid any level of exposure.

(ii) Ozone another gaseous disinfectant to consider for whole room disinfection. This chemical has been used for decades for water treatment, as it inactivates a wide range of micro-organisms, but the benefit of using ozone in the food industry is that High reactivity, penetrability and spontaneous decomposition into a non-toxic product make ozone a viable disinfectant for use in food production areas.

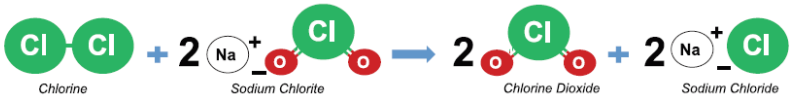
Due to its reactive, unstable nature, ozone is produced at the point of use. Ozone generators effectively pass air through a high-energy source, such as UV light or corona discharge within the equipment, which leads to the formation of ozone. A typical decontamination cycle consists of three phases in a one-step process: humidification to 70–80%; decontamination, where the ozone vapour concentration increases rapidly to 8–25ppm and is maintained at an optimum biocidal level by the ozone generator; and aeration. Manufacturer utilizes a biocidal quenching agent that further mops up the remaining ozone leaving the room clean, safe and fresh for immediate reoccupation. Cycle times vary depending on the area volume, desired level of decontamination and area contents, but are typically between 30 and 90min.

Portable ozone generators are now available and have discharge units and fans to create the ozone at concentrations between 0.05 and 5 ppm and catalytic converters to convert ozone to oxygen, at the termination of the exposure period.

(iii) Chlorine dioxide

Chlorine dioxide (CD), is a synthetic, green-yellowish gas with a chlorine-like, irritating odor. Its boiling point is 11°C and it is effective against a broad range of organisms (highly effective against Fungi, viruses, bacteria and spores), non-carcinogenic, residue-free, and has been U.S. EPA-approved for a variety of chambers including rooms (clean-rooms, holding rooms, surgical suites and procedure rooms).

Chlorine dioxide is an unstable gas that dissociates into chlorine gas (Cl_2), oxygen gas (O_2) and heat. This gas rapidly expands and penetrates the crevices of the area to be decontaminated. There are many ways to generate CD, but the common method for gas generation is using a safer, dilute 2% chlorine gas, which passes over sodium chlorite cartridges and produces a pure chlorine dioxide gas with no byproducts delivered to the chamber (See Fig 3). This is one of the main differences between gaseous CD and liquid chlorine dioxide. With the liquids, acids are used to generate the CD and this liquid is therefore acidic and the source of the issues with corrosion when using liquid CD.



Reaction of chlorine gas with the salt sodium chlorite:

Reaction of chlorite ions from sodium chlorite reacting with acid in presence of water

CD is applied in low concentrations (360 ppm to 1800 ppm), has short contact times compared to formaldehyde (0.5 to 2 hours), is non-flammable at use concentration, water soluble and remains in solution as a dissolved gas, and it does not hydrolyze to any appreciable extent. Furthermore, no post exposure cleanup is required and it can be directly vented or scrubbed at the end of exposure and the aeration is much faster in CD.

CD is easily scalable to large sizes in both empty rooms and rooms filled with equipment. Typically, one generator is required for every 30,000 cubic feet. It does not have issues with large spaces, multiple rooms or equipment filled rooms since it is a gas at room temperatures. As with all gaseous and vapor methods, fans assist in the dispersal and speed up the distribution time. ClorDiSys Solutions and DuPont™ Anthium Dioxcide® are commercially available chlorine dioxide for decontamination.

(iv) Hydrogen Peroxide Vapor

Vapor methods using hydrogen peroxide have more benefits compared to misting/fogging and manual wiping methods. Vapor hydrogen peroxide (VHP) is effective against a broad range of organisms is non-carcinogenic. Fumigation with vapourised hydrogen peroxide (VHP) is a technique that has been widely used for disinfection in the pharmaceutical environment, including production filling lines, sterility testing areas and production facilities and may be an alternative to fogging for the food industry. The application is dry, so there are no issues with the presence

of electrical equipment and the vapor is able to penetrate the whole room.

A typical decontamination cycle consists of four phases in a one step process (Fig 1). The phases are: dehumidification, to reduce the relative humidity to less than 40%; conditioning, where the hydrogen peroxide is vapourised; decontamination, which consists of a steady injection and re-circulation of the VHP to maintain the concentration, typically 0.1 to 3.0 mg/L, for the desired exposure time; and aeration, where the residual vapor is catalytically decomposed into water vapor and oxygen.

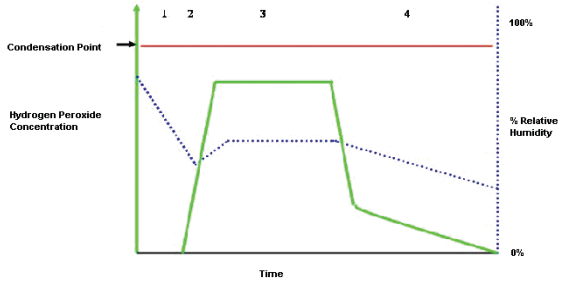


Fig 1: Typical VHP Decontamination Cycle: Four stages: (1) Dehumidification, (2) conditioning, (3) decontamination, and (4) aeration.

Vapor is not a mist and is therefore not subject to the gravitational effects that limit sprays, mists, or foams. VHP is generated by heating a 30%-35% solution of hydrogen peroxide (109°C boiling point for 35%) until it reaches the vapor phase. This vapor is then delivered to the room. Overall, decontamination times will depend on factors such as the VHP concentration and the temperature of the environment but they are generally in the order of 2 to 4 hours. It should be noted that microorganisms classified as catalase positive may be more resistant to disinfection

by low concentrations of hydrogen peroxide (Fig 2 for Resistance of Microorganisms).

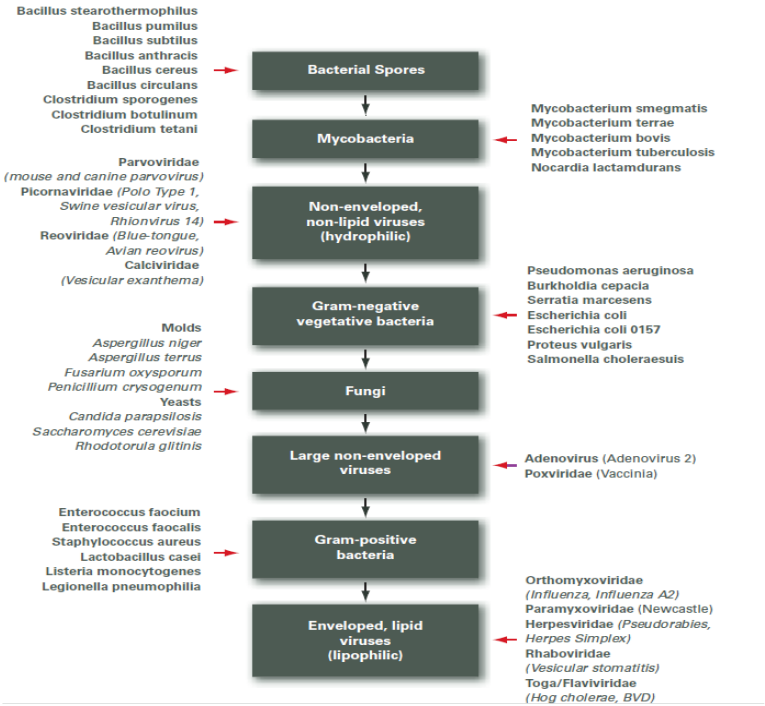


Fig 2 Descending order of microbial resistance to VHP.

Although the vapor method is typically easier and better than manual wiping or fogging, it has some drawbacks. Hydrogen peroxide tends to form strong hydrogen bonds between the molecules, limiting its movement in air (Herd, 2005). This makes the placement of injectors and circulation fans extremely critical. As a vapor, VHP is subject to condensation caused by temperature differentials and differences in thermal masses between objects of different sizes and materials. One way to help the vapor methods achieve better success is to have tighter

control of temperature gradients throughout the room. Additionally, VHP does not penetrate water. Therefore, in the cleaning step, the user must take this into account and ensure that water is not present in the environment. Drawbacks aside, the vapor methods have the benefit of removing the human factor where some surfaces might accidentally be missed and it tends to be safer as it allows the operator to be outside the room.

There are two primary systems available that use VHP: one uses a "wet" process and the other a "dry" process where visible condensation is avoided (Ref Table 3). Both generate the vapor in the same way such that liquid hydrogen peroxide is heated up, or vaporized to deliver it to its target. In the dry process, the relative humidity (RH) in the room must be lowered before injecting the vapor. The VHP is maintained below the condensation point to prevent condensation of VHP on the surfaces within the room. If condensation does occur, this can lead to surface damage.

Table 3: 'Wet' versus 'Dry' Hydrogen peroxide vapor

Sterilization process	Dry	Wet (condensation)
Repeatable process, easily validated	Yes	No, especially larger volumes
Reach low humidity levels	Yes	No
Control of H_2O_2 concentration	Yes	No, only condensation level at one point in an area
Typical use concentrations	0.1-2 mg/l	Unknown, variable
Aeration time	Short	Very Long
Material compatibility	Very Good	Poor
Capacity	Range for small areas to very larger areas	Up to 3500 ft3
Mobile	Yes	Yes
Available as a modular system	Yes	No
Safe on electronics	Yes	Not recommended

In the wet process, the vapor is generated in the same manner, but the RH in the room is not lowered prior to injecting the vapor. This decreases cycle time, but the user must be aware of condensation patterns generated during the cycle development period and try to minimize heavy condensation in particular areas to reduce corrosion. This is usually accomplished during the setup and cycle development. One drawback of the wet method is that when the ambient RH, or the room temperature, is different from when the cycle was developed, the injection rate should be modified to reflect this difference in starting RH levels to keep the condensation constant or repeatable.

VHP has additional benefits of a short contact time of 1-4 hours, no post exposure cleanup is required (the VHP is catalytically converted or directly vented), and the concentrations are low (720-1500ppm) compared to formaldehyde. Typical bio-decontamination times will depend on the VHP concentration and room temperature (See Table 4). VHP is scalable to large sizes in empty rooms, but has trouble with rooms containing equipment or fixtures. The equipment tends to block the flow of vapors and injection points need to be spread out and fans used to help distribute the vapor. It also has issues with large spaces since it exists as a vapor and not a gas. This is a limiting factor with VHP in many scenarios.

Table 4: Effect of VHP concentration and time

Temperature (°C)	Concentration (mg/L)	Concentration (ppm)	Typical D-value
4	0.1-0.5	350	8-12min
25	1-2	750-1500	1-2min
37	3-4	3000-5000	0.5-1min
55	10-12	7000+	1sec

UV light as a method of water disinfection has been researched extensively but equipment has now been designed to apply the technique for disinfection of surfaces and the air. Conveyor belt systems and barrier tunnels have been developed to enable disinfection to be carried out on surfaces where a dry chemical-free disinfection method is required.

The UV light in the range of 185 – 400nm, also known as UV-C, has been shown to be antimicrobial, with the optimum wavelength at 254nm. The UV-C is generated by either low (15–100W) or more powerful medium pressure lamps (0.5–5kW) and the dosage required will be dependent on the microbial contaminant, with fungal spores requiring a higher dosage than vegetative bacteria. The benefit of UV light is that it is a non-contact method, no chemicals are used and therefore there is no taint or residue. To decontaminate an area, a portable UV lamp is placed in the center of the room and the lamp is activated by a wireless remote. Once activated, an array of sensors within the equipment measure the germicidal UV-C energy reflected back to the unit and calculate the time required effectively to provide disinfection to all shaded areas within the room.

Titanium dioxide/ultraviolet light: Surface coatings have been developed using nanotechnology that make surfaces easier to clean or 'self-cleaning'. One coating, widely used due to its non-toxicity, chemical stability and capability for repeated use without the loss of catalytic activity, is titanium dioxide (TiO_2).

This coating can demonstrate two photo-induced responses: the first is photocatalytic and activated by the presence of UV light at wavelengths <385nm, and the second is a super hydrophilic response that reduces the

surface tension of water on the surface and improves cleanability. When the TiO_2 coating absorbs UV radiation from sunlight or an illuminated light source, in the presence of oxygen and water, it will produce pairs of electrons and holes as the electron of the valence band of TiO_2 becomes excited. The excess energy of this excited electron promotes the electron to the conduction band of TiO_2, creating a negative-electron and a positive-hole pair. This stage is referred to as the 'photo-excitation' state. The positive-hole of TiO breaks apart any water molecules present to form hydrogen gas, H_2O_2 and hydroxyl radicals (OH-) and the negative-electron reacts with oxygen molecules to form super oxide anions (O2-). These radicals are able to destroy bacteria and will therefore be effective in reducing bacterial contamination on coated surfaces.

Ionization: Equipment has also been developed to disinfect air by a process termed as ionization. This involves air, which naturally contains moisture, being passed over ionizing tubes emitting a high voltage discharge, such as a corona, to produce positively and negatively charged ions, such as hydroxyl radicals (OH-) and super oxide anions (O2-). These ions attract the naturally charged airborne micro-organisms, bonding with them and removing them from the air where they are deposited onto special grounded collectors on walls and floors. Constant disinfection is maintained by distributing a controlled amount of positive and negative ions. There is now the possibility of developing this technique further to treat surface contaminants, as well as airborne micro-organisms. Some commercial units combine non-thermal plasma and UV catalysis to produce a continual supply of hydroxyl radicals to destroy micro-organisms both in the air and on surface contact. The hydroxyl radicals that condense on contaminated surfaces can kill the bacteria

within hours. This technology can be adapted to specific environments and applied as portable stand-alone units or incorporated into HVAC systems.

Critical Factors to Select the methods/Fumigant

Critical factors to address before using these techniques include: (a) identifying areas where the decontamination processes can be applied, (b) any health and safety issues (Table 5) related to using the technique and the practical considerations related to their use in the food processing environment (c) The level of disinfection that these systems can achieve also needs to be determined, as some may achieve decontamination of all exposed room surfaces, such as ceilings, walls, floors and equipment; while others may include some penetration into equipment to contact indirectly exposed surfaces. (d) They may also provide disinfection of the air in the area being treated.

Cycles Development: Factors

The following are the critical factors that affect the decontamination process.

1. Volume
2. Room Shape
3. Shadow areas/Loading space
4. Temperature
5. Starting relative Humidity
6. Injection Rate
7. Wet surface in chamber/Room

Table 5: Safety Comparison of Fumigation Methods			
	Chlorine Dioxide	**Vapor Phase Hydrogen Peroxide**	**Formaldehyde**
8 hr TWA (time weighted average)	0.1 ppm	1.0 ppm	0.75 ppm
Odor Detection	YES At 8 hour safety level	NO	YES
Carcinogen	IARC—NO ACGIH—NO	IARC—NO ACGIH—YES (confirmed animal carcinogen)	IARC—YES ACGIH—Suspected
Able to be Vented to Environment	YES	YES	NO
Cycle Times (Risk of Exposure) 2500 ft^3 room	3-4 hours	6-12 hours	12+ hours
Typical Concentrations	360 ppm	750 ppm	8000 ppm
Good Penetration and Distribution	YES (gas)	NO (Vapor)	YES (gas)
Ability to Penetrate Water	Yes	NO	No
Equipment Location	Outside Room	Can either be inside or Outside depending on the manufacturer	Inside Room
Aeration Time 2500 ft^3 room	30-60 minutes	Typically Overnight	1 hour + cleanup

Equipment's used for Decontamination

Equipments/ Foggers/ Gas generators selection is based on the method of application (wet or dry) and area and dimension of the room. Various types and brands are commercially available in the market. Clordisys family of portable chlorine dioxide gas generators all automatically control the decontamination process are Cloridox-GMP , Minidox B, Minidox M for 1-70,000ft^3 and Minidox-L 300 ft^3 (8.5 m^3). Radiant enterprises has Dry aerosol fogger Aerojet STERIZ™, Yanthra 05 and 09 for decontamination

Diversey has Typhoon ULV Cold Fogger for Decontamination and spray.

Work Instructions:

A. Portable 4-Direction Fogger with compressed air (Figure 3)

1. Test the equipment with water only prior to any chemical use.
2. Place the chemical into a container of water for testing.
3. Open main supply air valve and adjust each nozzle valve to optimize to be fine fog.
4. Now ready for chemical fogging.
5. Run fogging as the controlling time.
6. When finished fogging, deactivate the air supply.
7. Follow other specific recommendation by the suppliers.

Operation:

1. Connect air supply and at the bottom of stand.
2. Put the chemical tube into the chemical tank.
3. Preferable height shall be adjusted by using L – knobs and tightens the L-knobs to secure.

Fogger with compressed air (Figure 3)

B. Fogger (Electric motor Operated-(Fig 4-6))

1. With its powerful electric motor, fogger distributes the fine droplets evenly over the affected area and delivers a particle size between 5 to 40 microns. The needle dosage control knob allows a liquid output flow from a lowest output of 10 ml/min in the range to a maximum of 170ml/min to create heavy mist depending on the viscosity of the liquid to be fogged.
2. The only maintenance required is an occasional cleaning of the liquid filter (20) and the PP filter (29). Remove the filter and rinse it with running water to remove the clinging particles.
3. Avoid contamination when changing chemicals: Fogging with clean water (or appropriate solvent) through unit and rinse tank thoroughly.
4. Periodically check the cleanliness of the air filter (11). If the motor does breathe a sufficient quantity of clean air, the fogging operation will be inefficient and the motor could be overheated.
5. Check seal, gasket, tube and hose for leakage. Replace if necessary. Make sure the all the filters and solution filter are clean.

Operation:

1. Make sure the plug (3) is disconnected from the power socket.
2. When you use the appliance for the first time or if you have not used it for a while, remove the closure ring (5) and check the tank (6) is clean.
3. Replace the power head (7), making sure the tank gasket (4) is in place and return the closure ring (5) to its position.

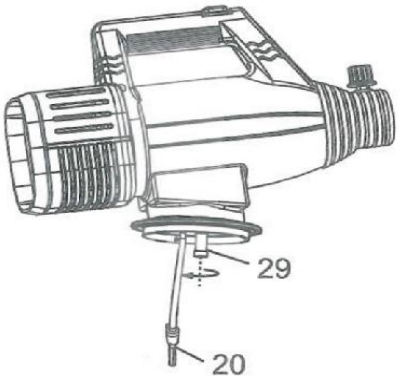


Figure 4

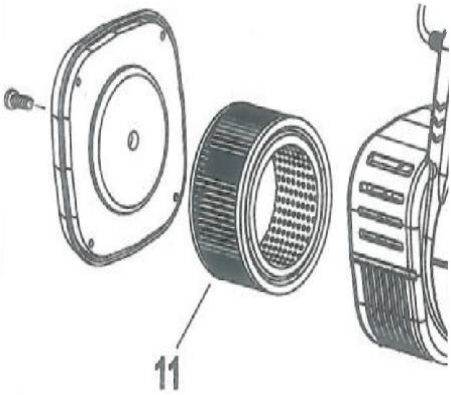


Figure 5

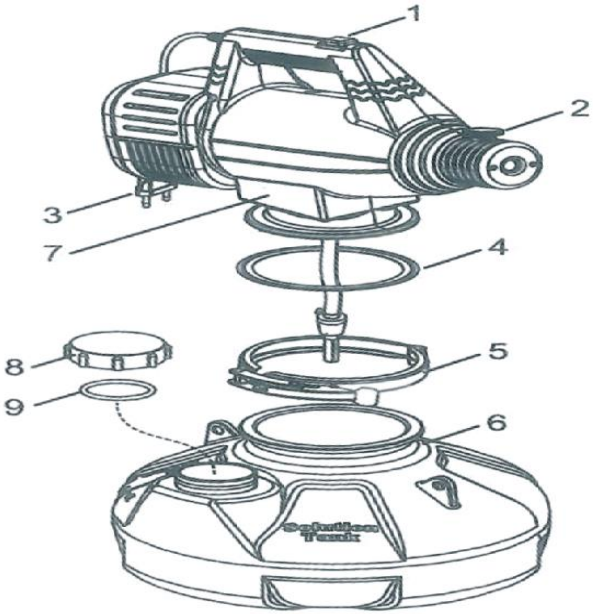


Figure 6

4. Pour the solution into the tank (6) then close the filling cap (8), make sure the O-ring (9) is in position.
5. Before connecting the power cord (3) to a power socket, make sure that
   - Flow control knob (2) on close position
   - Switch (1) is set to the off position.
6. Aim the nozzle in the required direction and switch on the appliance.
7. Adjust to flow control knob for the quantity of product to be distributed.
8. When using solution which creates foam, to keep foam from penetrating into the power head (7) to damage the motor (1), in any case, the foam level should be kept lower than the PE filter (29).
9. Plan your job in such a way that the appliance draws in as little fog as possible.
10. Work so that you leave the treated areas through untreated areas in the exit direction.
11. Once fogging is complete, close the control knob before switching off the appliance.
12. Remove residues of solution and empty tank, fog using warm water.

Detection of Decontaminants

Sensors and indicators are available to detect the concentration and presence of fumigants during a bio-decontamination process. For detection of low level (safety) concentrations Draeger Pac III hand held or wall mounted monitors (e.g., P/N4530010 with

hydrogen peroxide Sensor Head P/N 6809170) sensor system (handheld) or Draeger Chemical indicator Tubes 9 (such as Part #81 01 041) with a hand-aspirated pump are available to monitor VHP in adjacent areas or to confirm adequate aeration in a given area. Other Electrochemical and spectro-photometric sensors are available for detection and monitoring of higher VHP concentrations. Chemical indicators that indicate the presence of VHP at effective concentrations over time are available for routine monitoring or validation of VHP decontamination processes. Chlorine dioxide gas can be vented or scrubbed, depending on customer preference.

Fumigation with Hydrogen Peroxide (H_2O_2)

Hydrogen peroxide is a clear, colorless liquid, and more viscous than water. It is most commonly available as a solution in water.

Prerequisites:

1. Hydrogen peroxide (HP) is a surface decontaminant and may not penetrate dirt and detritus. Heavily soiled surfaces should be cleaned prior to decontamination with VHP.
2. Remove all personnel from area to be contaminated as well as any equipment and materials that are not compatible with VHP and high levels of moisture. Trash/waste receptacle contents must be bagged, sealed and left in place for surface decontamination prior to being removed from the room.

3. Open all cabinet doors, drawers, and doors to suites and minimize occluded/covered surfaces to facilitate penetration of VHP.
4. Shut off HVAC of area to be decontaminated when possible.
5. While absorbable materials can remain in the room during bio-decontamination (e.g., paper, clothing, fabrics, etc.) the presence of a large quantity of absorbable material will extend gassing time and aeration time to account for peroxide absorbed.
6. Turn off equipment that may operate above or below ambient room temperature (e.g., autoclaves, incubators, refrigerators, and cold rooms) and allow them to return to ambient room temperature prior to cycle initiation to ensure VHP distribution.
7. Smoke detector disengagement responsibilities and sealing of space.

Decontamination Procedure:

1. Fumigation with hydrogen peroxide first requires a procedure to dehumidify the area to prevent condensation or proper humidification needs to be maintained.
2. Once the humidity and temperature levels are stabilized, a 35% / 59% hydrogen peroxide solution is vaporized via a generator (fogger) and released into the room/area.
3. Place the Fogger/generator in the center of room for even VHP distribution (as per equipment operating instructions).
4. To get the sporicidal activity concentration shall be of 0.5-3 mg/L at 25°C Vaporized hydrogen peroxide.
5. During the inactivation phase, the hydrogen peroxide concentration is maintained at a maximum concentration level.

6. The percentage of hydrogen peroxide that is consumed by absorption or decomposition is resupplied to the system.
7. The overall fumigation time is shall be based on the area of fumigation/suppliers recommendation.
8. In Aseptic filling area ($56m^3/1977ft^3$) following condition may be considered for fumigation.

Condition	Airflow: $34m^3$/hr, H_2O_2 injection:10g/min, Time : 40 min
Sterilize	Airflow: $32m^3$/hr, H_2O_2 injection:6g/min, Time : 80 min
Aerate	Airflow: $38m^3$/hr, Time : 4h or AHU may be used

9. Aeration is necessary to remove the H_2O_2 by using AHU or natural aeration time.
10. Residual H_2O_2 shall be monitored by sensors (should be <1ppm).
11. Enter room adhering to appropriate practices to prevent re-contamination of the area.
12. Wearing gloves retrieve all Chemical indicators (CIs).
13. Inspect CIs to ensure adequate color change and validate the process.

Health and Safety

1. Hydrogen peroxide (HP) is a strong oxidizer and is irritating to the eyes, skin, and mucous membranes. It is imperative that all personnel using HP wear the appropriate personal protection equipment.
   a. Protective eyewear (e.g., goggles or face shield) must be worn when performing procedures that could result in HP coming in contact with the eyes.
   b. Protective eyewear, impervious sleeves and gloves (e.g., neoprene or vinyl) are required when handling concentrated HP solutions (i.e., changing or filing bottles).
   c. Wash hands after handling HP.
   d. Flush skin/eyes with water if come in contact with HP.

e. HP spills should be cleaned-up with water.
2. If you must enter an area briefly during or immediately after fogging with HP, coverall with hood and boots (or long sleeves, long pants, hair cover and shoe covers), gloves, snug-fitting goggles, and half-face respirator with organic vapour filters and a particulate filter are required.
3. HP should be stored in the dark at ambient room temperature.

Effectiveness

The chemical indicators (CI) may be used for check the proper decontamination/fumigation process. (CI will change color and fades from blue towards white when exposed to the parameters i.e., time, concentration and micro-condensation of the VHP surface decontamination process).

REFERENCES

1. Mark A. Czarneski, Selecting the Right Chemical Agent for Decontamination of Rooms and Chambers, Applied Biosafety, 12(2) pp. 85-92: 2007.
2. Dr. Karen Middleton, Whole room disinfection: A new concept in food industry sanitation article in Issue 1 New Food Magazine 28 February 2008 (https://www.hpcimedia.com/enews/Cleanroom-Technology).
3. J. E. Meszaros, K. Antloga, C. Justi, C. Plesnicher, and G. McDonnell, Area Fumigation with Hydrogen Peroxide Vapor, Applied Biosafety*, 10*(2) pp. 91-100, 2005.
4. VHP (Vaporized Hydrogen Peroxide) Bio-decontamination Technology, Technical Data Monograph Published by STERIS Corporation - January 2003.
5. *Technical Note*: Thermo Scientific Biological Safety Cabinets Fumigation Methodologies.
6. ClorDiSys (www.clordisys.com) Decontamination and Sterilization, Equipment and Services.
7. Formaldehyde replacement, Workshop preceding's organised on 11-12 January 2011 at Lelystad by Central Veterinary Institute, Wageningen.
8. Samantha Kimball, Paul Bodurtha and F.Gudgin Dickson. A Roadmap for investigation and validation of Dry Fogging as a decontamination Technology, Defense research and Development, Canada, December-2014.
9. Patrick Vanhecke, Volker Sigwarth and Claude Moirandat, A Potent and Safe H2O2 Fumigation Approach, PDA J Pharm Sci and Tech, 66, 354-370,2012.
10. Room Decontamination with Hydrogen Peroxide Vapour, Industrial Review, STERIS Corporation, 2000.

Fumigation -for decontamination

I find this bulletin:

Useful ☐ Informative ☐

Only entertaining ☐ Boring ☐

I think the format of this bulletin needs/does not need change.

I would like information in any subsequent issue on --------

Please send your letters to:

Dr. DK Sharma
General Manager QA & PPD

National Dairy Development Board
Post Box No. 40
Anand 388001
Gujarat.

Fax. No. +91(2692) 260-157
Email: dksharma@nddb.coop /
FSQ-milkcoops@nddb.coop