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Case Study: Exhaust Duct Decontamination Using Chlorine Dioxide Gas

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The exhaust ductwork in a laboratory at a major pharmaceutical company in North Carolina need replacement. Since the ductwork was used to exhaust BSCs for testing on HIV and HCV, special precautions would be required during the demolition. These special precautions would add cost, complexity, as well as a level of risk to the demolition crew. The typical method of demolition is t have the construction crew wear protective suits with proper PPE and masks. Holes would be dr or sections cut out from the ductwork and and the inside of the ductwork then sprayed or wiped down with sterilizing agents. The area beneath the ductwork would then need to be decontamina with sterilizing agents to remove any of the contaminants that accidentally escaped. For proper decontamination to occur, the sterilizing agent would need to reach all surfaces inside the ductwo at the proper concentration, for the time specified on its label. Because of the complexity of havir contractors remove contaminated ductwork, the company decided that a fumigation style decontamination should be performed.

There are typically considered three methods of fumigation for areas such as rooms. Of these, formaldehyde and vapor phase hydrogen peroxide would not be able to accomplish that amount ductwork decontamination. Formaldehyde is listed as a carcinogen and it leaves residues. Vapor phase hydrogen peroxide would break back down to a liquid because of the length of ducts and temperature gradients. The HEPA housings would also add additional challenges. The pharmaceutical company was familiar with the application of gaseous chlorine dioxide for area decontamination and chose to apply it for this ductwork decontamination. ClorDiSys Solutions, In was called in to fumigate the contaminated ductwork with chlorine dioxide gas.

CHLORINE DIOXIDE

Although chlorine dioxide (CD) has “chlorine” in its name, its chemistry is radically different from t of chlorine. CD oxygenates products rather than chlorinating them and thus trihalomethane (THM) formation does not occur.[1] Therefore, unlike chlorine, CD does not produce environmentally undesirable organic compounds containing chlorine.

Chlorine dioxide is a true gas at normal use temperatures and therefore is not susceptible to condensation issues and temperature gradients. It has a yellowishgreen color, which allows its concentration to be precisely monitored and controlled by a UV-VIS spectrophotometer. This allo tight process control from beginning to end of a decontamination cycle.

Chlorine dioxide has been recognized for its disinfecting properties. Gaseous CD has been show be more effective than liquid CD when applied in equal concentrations and times.[2] Chlorine dioxid both gaseous and aqueous phase, is a strong oxidizing agent and has about 2.5 times the oxidati

capacity of chlorine. [3] Additionally, CD gas has been approved for use as a sterilant/decontamina by the U.S. EPA. Both gaseous and aqueous phase CD has been shown to be an effective saniti agent that has broad and high biocidal effectiveness. Aqueous CD has been reported to effective inactivate bacteria[4,5,6] including pathogens,[7,8] viruses,[9,10] bacterial spores,[11,12] and algae.[13]

PHYSICAL SITE

The laboratory consisted of a four-room BSL-2 area and a smaller, two-room BSL-3 area. There were a total of 14 BSCs with exhaust ductwork that required decontamination and two ceiling exhausts. This BSL lab was on the third floor of the building. The two exhaust fans and two HEPA housings for the lab were located on the buildings fifth floor. Bubble-tight dampers isolated the di and clean sides of both HEPA housings.

SITE PREPARATION

Setting up for the decontamination of the exhaust ductwork for the facility proved to be the most timeconsuming, labor-intensive part of the project — taking approximately seven hours. This was because the BSL area was on the third floor and contained 15 exhaust points, 13 of which were BSCs fitting were attached to all exhaust points in order to create a gas-tight connection. These plates were sealed to each exhaust point including the BSCs.

Each BSC was then thoroughly sealed using a combination of plastic and tape. Camlock fittings v also put on the HEPA filter housings located on the fifth floor. Hoses were run from the fifth floor down to four distribution manifolds on the third floor. Each distribution manifold consisted of four blowers, four distribution hoses, one CD gas sample port, and one humidification input port. Each the individual distribution hoses went to an individual BSC (Figure 1).

Air was pulled from the dirty side of the HEPA housing and pulled down the two floors and blown each BSC, where it was returned back up to the HEPA housing through the exhaust ducts (Figure The building's HVAC supply and exhaust systems were deactivated and the bubble-tight dampers the dirty side of each HEPA housing were closed. Gauges to measure relative humidity were pla in each BSC, allowing the internal conditions to be monitored during the humidification phase of th decontamination.

One chlorine dioxide gas generator was set up, and gas injection tubing was run to one BSC in th BSL-2 area and to one BSC in the BLS-3 area. The gas was then pulled through the exhaust sys on the fifth floor and down to the distribution system and then into each BSC.

The CD concentration was monitored throughout the process via a ClorDiSys EMS system which was located outside of the area to be decontaminated. Sample tubing was run to each of the fou distribution manifolds to allow the gas concentration to be monitored and controlled at all times throughout the ductwork. This ensured a successful cycle even if slight leaks from the exhaust we present. More importantly, this step assures that people are alerted if the desired gas concentra was not reached and therefore complete deactivation of spores did not occur.

Figure 1: Decontamination Equipment Attached to BSCs

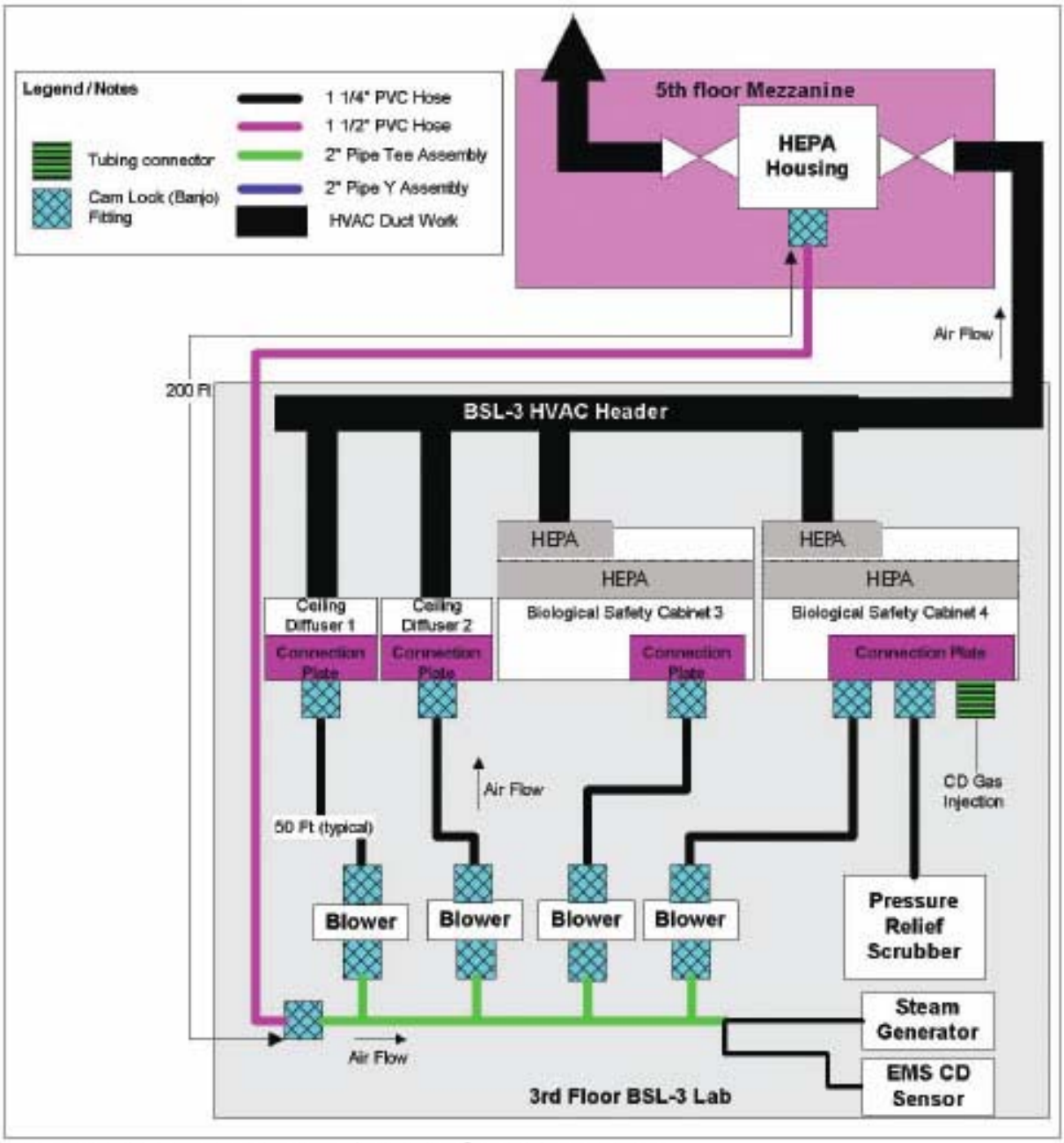

Figure 2: Decontamination Layout of a BSL-3 Area

DECONTAMINATION EVENT

The decontamination effort was approached as if it was to obtain a 6-log sporicidal reduction. A sporicidal reduction is the most difficult to achieve as compared with viruses and other organisms sporicidal reduction requires humidity to soften the spore walls in order to allow the gas to penetr the organism and obtain kill. This is true with all decontaminating agents.

The chlorine dioxide decontamination process consists of the following steps; humidification to so the spore walls, the introduction of CD gas into the area to reach the desired concentration, a dw period (called exposure) where the gas just sits for a period of time to obtain the desired kill leve and finally aeration to remove the gas by bringing in fresh air and exhausting up the stack.

The humidification range to soften the spore walls is 60% or higher with an optimal level of 65 – 70%. The exposure level and time targeted to obtain a 6-log sporicidal reduction is 1 mg/liter (360ppm) at two hours or 2 mg/liter at one hour. This equates to 720 ppm-hours of exposure. At

end of exposure, the gas is aerated by bringing in fresh air and exhausting up the stack until the concentration drops to 0.1 ppm. This is the 8-hour safety level as well as the odor threshold leve

The actual steps used to decontaminate the ductwork differed slightly. The humidity was accomplished by using a portable steam generator to inject humidity into each distribution manifo The blowers on the distribution manifold pulled in the moisture and then blew the humidity through 50 feet of hose, which went into each BSC where a minimum humidity level of 70% was reached Once the conditioning time was completed, the charging step was first initiated and was set to bı the concentration up to 1 or 2 mg/L of CD gas then held for one to two hours depending on the concentration reached. This time would yield a target exposure of 720 ppm-hours (1 mg/l 360 pp The actual CD gas concentration was measured throughout the cycle by using a UV-VIS spectrophotometer.

The target exposure as described above was for 720 ppm-hours and this was expected to achie greater than 6-log reduction. The actual exposure concentration was greater than 1021 ppm–hou at the lowest concentration.

Aeration was initiated after a two hour charge/exposure. The bubbletight dampers on the clean s of the HEPA housings were opened and both of the exhaust fans on the third floor were energize After 15 minutes, the levels of CD were no longer measurable and the BSCs were safe to unsea without personnel protective equipment. Note that the detection level of the chlorine dioxide safet sensor used was 0.1ppm which is the 8-hour (TWA) threshold as indicated by OSHA, 0.3 ppm b the short term exposure level (STEL).

RESULTS

A total of 15 *Bacillus atrophaeus* biological indicators (BIs) were placed in each BSC and the tw room exhaust vents to validate the gaseous CD decontamination. None of the biological indicator *B. atrophaeus* produced growth.

The results of the decontamination cycle yielded a greater than 720 ppm-hr decontamination time which is more than adequate to provide a 6-log sporicidal reduction. At the end of aeration, the C monitors showed levels below 0.1 ppm with no residual chlorine dioxide odor (below the OSHA worker safety levels of 0.1ppm). All biological indicators that were placed in each of the BSCs w negative after the seven day incubation period with the control BI being positive.

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