Effect of particle size and H_2O_2/PAA concentration on the efficacy of an aerosol decontamination system for items entering swine farms

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Introduction

The swine industry continues to invest significant effort to heighten biosecurity practices within production systems. Aerosolized chemical disinfection or fumigation of supplies is a common practice to mitigate pathogen entry onto swine farms. However, recent evaluations state the use of commercial foggers results in inconsistent and incomplete disinfectant contact to all sides of objects.[1,2] Current fumigation systems require manipulation of objects, a large volume of disinfectant use, and result in impractical saturation of objects to overcome the lack of empirical disinfection.[3]

Currently used in hospitals and pharmaceutical clean rooms, a "Dry Fog System" (Cantel Medical Inc., DFS) has been implemented as a more effective fumigation process.[6] Dry fogging utilizes a liquid disinfect and compressed air to generate an ultrafine droplet.[6] Unlike a wet fog, the micro-droplets do not settle onto surfaces right away and avoid any excessive condensation or saturation of liquid to the room and objects.[6] Peracetic acid (PAA) and hydrogen peroxide (H_2O_2) are commonly used as oxidizing agents that fully biodegrade to acetic acid (vinegar), O_2, and water through the DFS.[5] As a disinfectant, peracetic acid (PAA) has been widely used in the food processing, dairy, and beverage industries for its non-toxic byproducts, and enhanced lipid-soluble microbicidal effects superior to H_2O_2 alone.[6] Evidence has shown that a DFS using a combination of H_2O_2 and PAA is capable of inactivating microbial agents in the presence of a soil load.[6]

While upholding biosecurity standards is critical to protect the health of swine farms, recent fumigation chamber research would suggest this is a weakness in preventing pathogen spread. Use of dry fog shows promise to overcome the difficulty of current methods through the use of small particles. The objective of the study was to evaluate the effect of particle size and H_2O_2/PAA concentration on aerosol decontamination for supplies entering swine barns.

Materials and methods

An air-tight decontamination room measuring 1.75 × 1.42 × 2.51m (6.27m3) was used for this study. Humidity loggers were placed at 4 locations in the center of the room (labeled A, B, C, D) (Figure 1). A standard household de-humidifier was used in the treatment room to achieve the desired relative humidity (RH) start point < 60% for all experiments.[7]

Commonly utilized Hurricane Ultra II (Curtis Dyna-Fog, HUF) foggers produce a flow rate dependent median particle size of 14 to 26 microns.[4] The DFS produces a controlled median 5.9 um droplet to ensure even dispersion throughout the space comparable to gas or vapor.[5] Two proprietary blends of PAA and hydrogen peroxide (H_2O_2), Actril (A), and Minncare (M) (Cantel Medical) have been approved by the EPA for use as aerosol disinfectants in medical clean rooms with droplets averaging 5.9um.[5]

A (1% H_2O_2/0.08% PAA) and M (22%/4.5%) were used as the sterilant and were compared to Intervention (IVN, 4.25% H2O2) (Virox Animal Health). Three droplet sizes were compared, 5.9um (SD; DFS), 14 um, (MD, HUF@1 gal/min), and 26um (LD, HUF@4.5 gal/min). A dry fog nozzle connected to an air compressor was used to produce a small droplet (SD) size (5.9 um) when operated at a constant 75 psi. A HUF fogger was used at the low setting for a medium droplet size (MD) (14 um) and the high setting for a large droplet size (LD) (26 um).

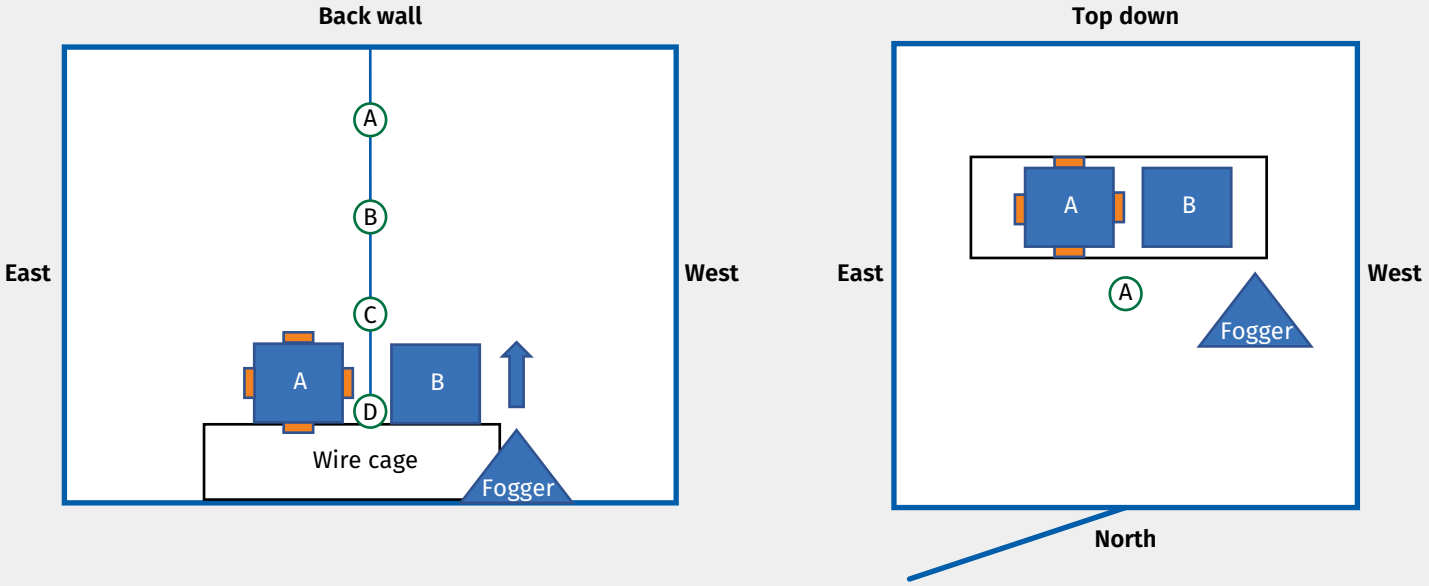
200 mL of disinfectant were applied at four concentrations: 1% H2O2/0.08% PPA (A), 1% H_2O_2/ 0.21% PAA (MC9.5), 2% H_2O_2/ 0.42% PAA (MC19), and 2% H_2O_2 (IVN) diluted in deionized water just before use. The delivery device was placed on the floor just off-center of the room. Two boxes were placed on a wire shelf and 5log and 6Log Geobacillus spore Biological Indicator (BI) strips were placed on all 6 sides of box A. BI strips are the standard method to assess cleanroom decontamination. They are a robust pathogen more resistant to decontamination than bacteria and viruses.[5]

The room remained sealed for 1 hour where the effective RH was maintained below 85% to prevent condensation and limited aerosol spread.[7] BI strips were incubated overnight at 55 °C in tryptic soy broth. If no growth was observed, it was interpreted as a reduction of a bacterial load equal to the concentration of the biological indicator.

Additionally, 1.0 mL of Ingelvac PRRS® MLV (MLV) was plated onto sterile petri dishes, treated by a direct spray of A and MC to validate that H_2O_2/PAA inactivates PRRSV. MLV inoculated petri dishes were also attached to all 6 sides of box A and subject to MD MC19 treatment. All viral samples were transported to the lab for virus isolation. 1.0 mL of D/E Neutralizing broth was added to each treated plate to inactivate any remaining disinfectant. 250 ul of solution were plated onto MARC-145 cells and incubated for 5 days at 37 °C where no cytopathic effects (CPE) were observed.

Furthermore, 1.0 mL of a manure slurry was plated onto sterile petri dishes attached to box A, treated with MD MC19 to challenge a variation in Log 5 and Log 6 reductions. The fumigated slurry plates subject to bacterial culture to compare BI strip log reductions and the ability of H_2O_2/PAA to decontaminate surfaces with organic material present.

Figure 1: Orientation of box sampling locations relative to room and aerosolized chemical source. Fogger was placed on the floor, BI strips were elevated 12" above the floor surface. The chamber was 1.75 × 1.42 × 2.51m (6.27m^3) in size.



Results and discussion

Decontamination effectiveness was dependent on both particle size and H_2O_2/PAA concentration. The results are summarized in Figure 2. The SDMC19 treatment resulted in a 5-log reduction on 18/18 sides and a 6-log reduction on 17/18 sides. MDMC19 treatment resulted in 12/12 sides having a 5-log but only 8/12 sides having 6-log decontamination. All other combinations had at least 1 side without a 5-log reduction.

Direct contact of A and MC and treatment of MD MC19 to MLV resulted in complete viral inactivation in all orientations within the treatment room. No bacterial growth was observed from MD MC19 treated manure slurry plates from each side of the treatment box.

These results indicate that to achieve decontamination of supplies entering a swine farm droplet sizes averaging less than 14um with H2O2/PAA concentrations greater than 4.2/0.13 ppm is required. Optimal disinfection was achieved with droplet sizes < 6um.

Due to the safe biologic nature of H2O2/PAA, the non-toxic by-products may be safely applied in numerous areas of swine farm supply entry. With no soaking or residue when applied through a DFS, this makes it a suitable decontamination practice for personal items, covered lunches, and various farm supplies.

This study demonstrates the dry fog system's ability to inactivate resistant pathogens with or without the presence of organic material. The DFS technology can be implemented in pre-existing decontamination rooms and offers a safer alternative to traditionally used harmful chemicals. These data support that effective aerosol decontamination can be achieved with droplets smaller than currently used in swine barns when using oxidative disinfectants at high concentrations.

References

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Figure 2: 5 & 6 Log Biological Indicator strip data. Percent decontamination achieved represents the proportion of sides negative for bacterial growth following treatments of MC, A, and IVN at various particle sizes.