The Science of Aerosolized Hydrogen Peroxide

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Agenda

Surface Spread HAIs

- Surface Spread Pathogens
- Pathogen Regrowth

Chemical Disinfectants

- Chemical Comparisons
- Why Hydrogen Peroxide

Aerosolized Hydrogen Peroxide (aHP)

- Pathogen Kill Mechanisms
- Dosage & Safety Guidelines
- The Technology of Breezy Blue

Clinical Data

- Lab Testing
- Case Studies

Surface HAIs

Surface Spread Pathogens

Bacteria

- *Staphylococcus aureus* (including MRSA): can survive on surfaces for days or even months.
- *Clostridium difficile*: spore-forming bacteria can persist for more than 5 months.
- Vancomycin-resistant enterococci (VRE): can survive on surfaces from 5 days to 4 months.
- *Acinetobacter baumannii*: known for its persistence on hospital surfaces from 5 days to over 5 months.
- Gram-negative bacteria: organisms like *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, and *Enterobacteriaceae* can thrive in biofilms on surfaces.
- *Escherichia coli*: commonly found on hospital surfaces and can be transferred to skin upon contact.

Viruses

- Norovirus: easily spread through contaminated surfaces and can persist for up to 12 days.
- Coronaviruses (including SARS-CoV-2): can survive on various surfaces (plastics, metals, etc.) for days.
- Influenza virus: can survive for 24-48 hours on non-porous surfaces and can be re-aerosolized during cleaning, leading to cross-contamination.
- Rotaviruses: highly infectious and can remain on surfaces for up to 60 days.

Fungi

- *Candida auris*: can survive on surfaces and medical equipment for up to 14 days.

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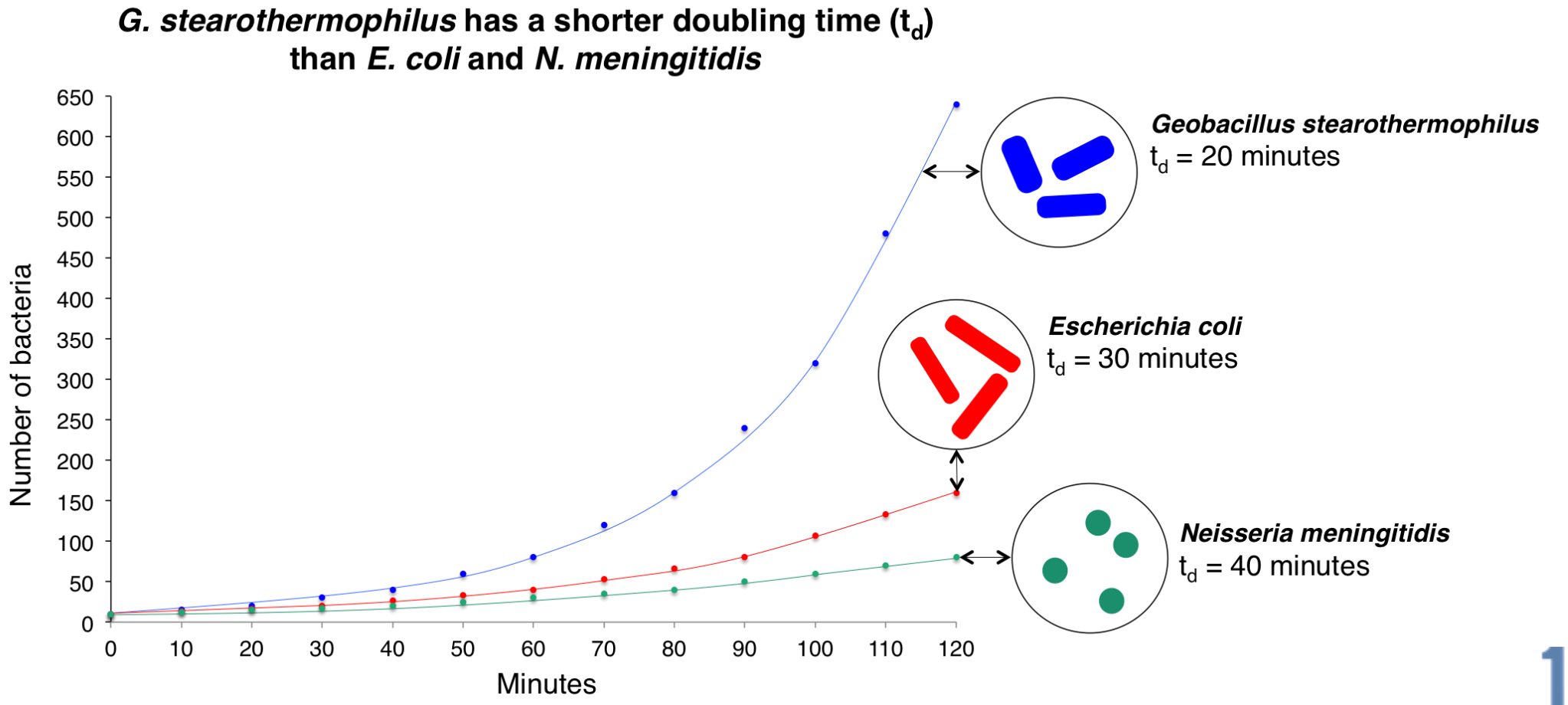
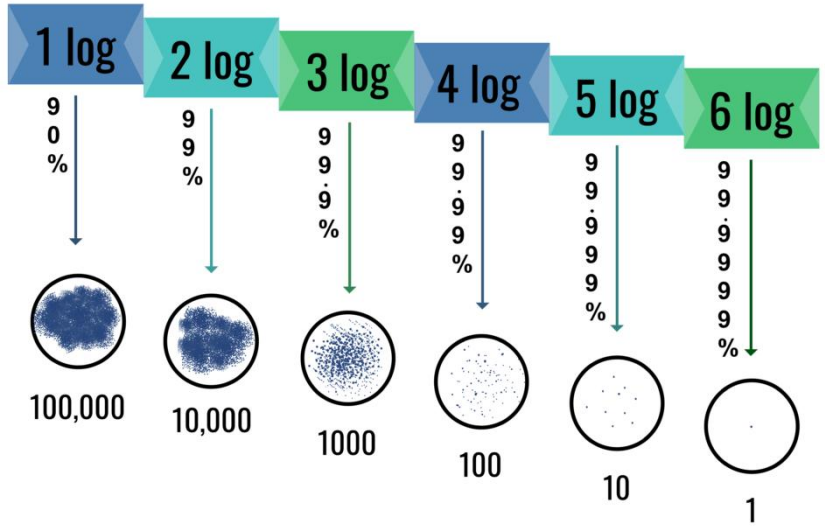
Pathogen Exponential Regrowth



Pathogen Exponential Regrowth

Doubling Times and Regrowth Times after various disinfection log kills within a laboratory environment

Pathogen	T_d (min)	T_r 4 Log (hrs)	T_r 5 Log (hrs)	T_r 6 Log (hrs)
Geobacilus	20	4.4	5.5	6.6
MRSA	30	6.6	8.3	10.0
C. difficile	70	15.5	19.4	23.3
C. auris	150	33.2	41.5	49.8



The growth medium is limited within real-world environments, and the growth rate tapers off as the population returns to the carrying capacity of the environment. Consequently, real-world regrowth rates are slower than laboratory conditions.

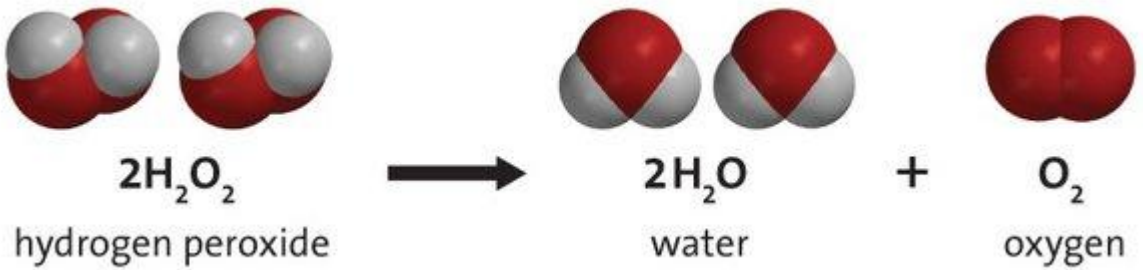
Chemical Disinfectants

Chemical Comparisons

Property	Hydrogen Peroxide	Hypochlorous Acid	Sodium Hypochlorite (Bleach)	Quaternary Ammonium
Chemistry	H_2O_2 (5-8%)	HOCl (0.05-0.1%) weak acid of chlorine gas dissolved in water	NaClO (5-10%)	Salts of $[NR_4]+$, where R is an alkyl, aryl or organyl group (0.1-2%)
High Level Disinfection (6-log kill), Sporicidal (e.g. C. diff)	yes	no	yes	no
Toxicity (skin, eye, swallow, inhale)	skin: irritant eye: irritant swallow: irritant inhale: irritant	skin: none eye: irritant swallow: irritant inhale: irritant	skin: severe burns eye: serious damage swallow: poisonous inhale: hazardous	skin: irritant to burns eye: irritant to damage swallow: harmful inhale: harmful
Residue/Rinse	no residue or rinse	no residue or rinse	requires rinse	leaves residue and requires rinse
Fogging compatibility	dry fog, biodegrades naturally	need to wet surfaces for efficacy	harmful if fogged	harmful if fogged
Material compatibility	broad compatibility, mildly corrosive on untreated metals & some plastics	broad compatibility in low concentrations, mildly corrosive on metals and plastics	corrosive on untreated metals & some plastics	broad compatibility, mildly corrosive on untreated metals
Biodegradable	breaks down into water and oxygen very quickly	breaks down into oxygen and chlorate	breaks down into carbon and water within 20 days	many quats are not biodegradable
Odor/fumes	none	none	hazardous fumes/odor	quat needs exhaust
Shelf life (unopened container)	1 year	days to few months	1 year	5 years
Cost	Mid	Mid	Low	Low

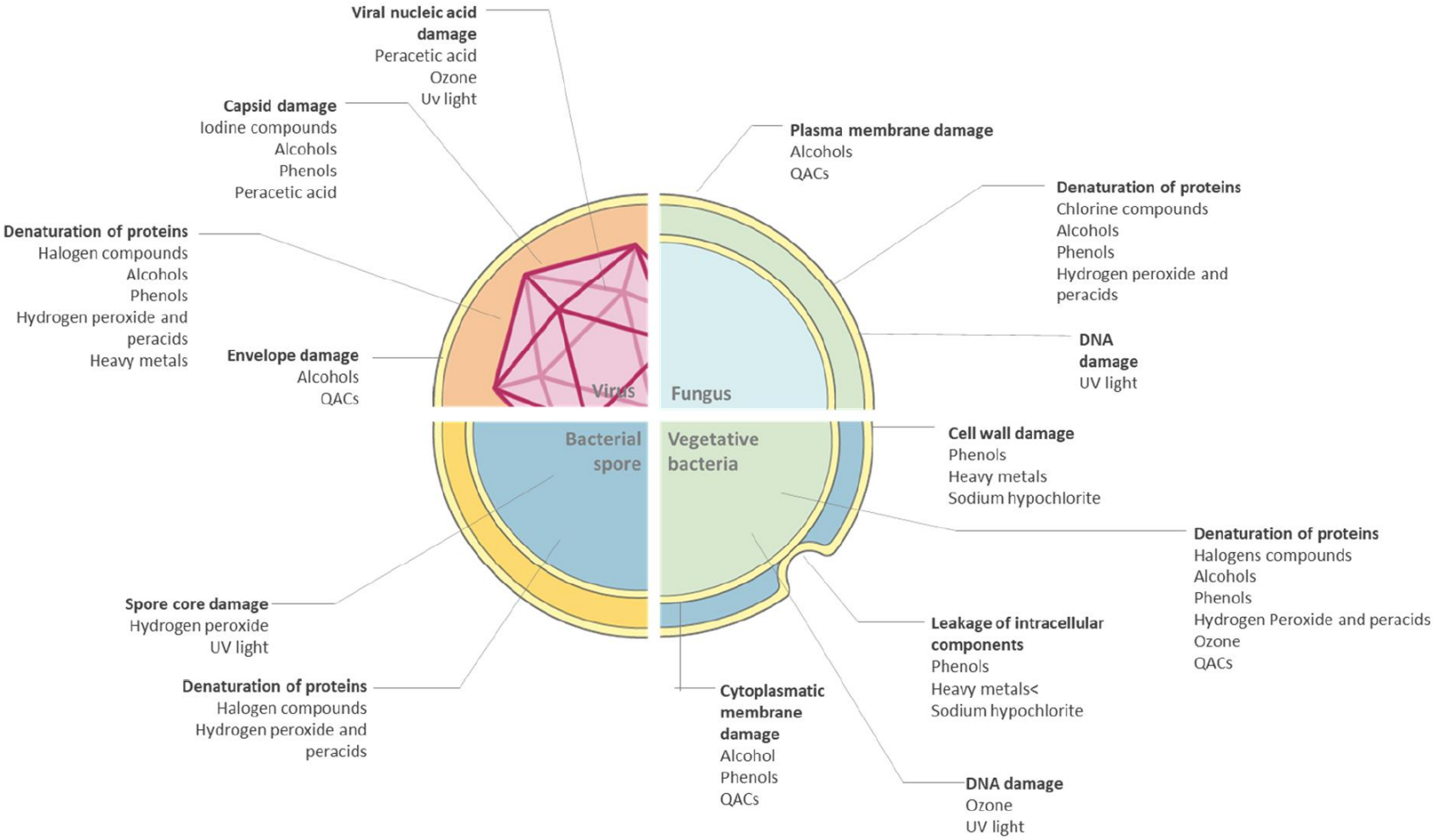
Why hydrogen peroxide for disinfection?

- Hydrogen peroxide (H_2O_2) exhibits broad activity against microorganisms
- Naturally occurring ecofriendly chemical, leaves no residue or harmful byproducts
- Good storage stability
- Compatible with most materials
- Active across a wide temperature range
- Hydrogen peroxide aerosol can penetrate all the areas of a room
- Aqueous solutions less than 8% (>92% H_2O) have a low toxicity, are safe to use, and don't require any special transportation precautions



Aerosolized Hydrogen Peroxide (aHP)

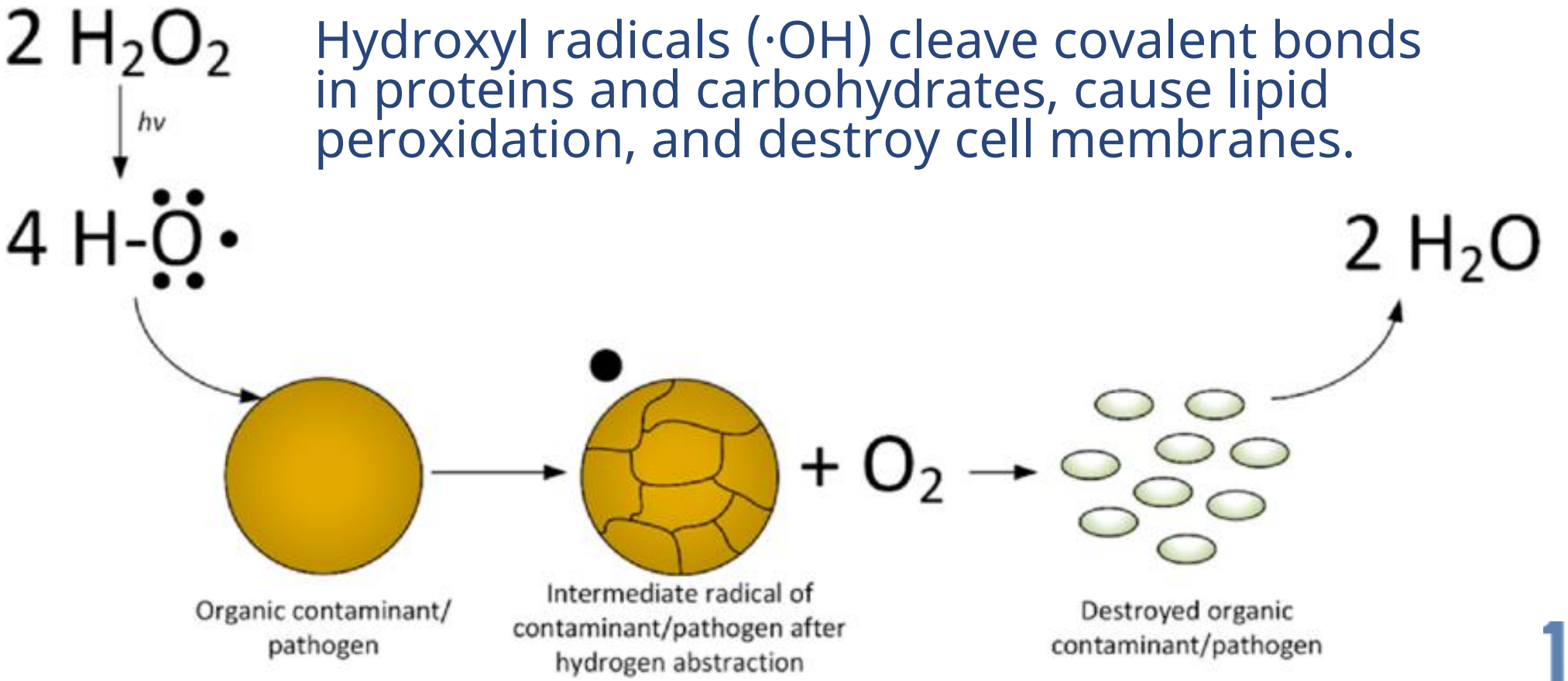
Disinfection Mechanisms



Source - https://pubmed.ncbi.nlm.nih.gov/34063833/

Chemistry of disinfection using H_2O_2

Hydroxyl radicals (·OH) cleave covalent bonds in proteins and carbohydrates, cause lipid peroxidation, and destroy cell membranes.



aHP comparison to VHP

Aerosolized hydrogen peroxide (aHP)

- Cold vaporization
- Fast H_2O_2 distribution
- Less H_2O_2 consumption
- Lower concentration H_2O_2 required
  - Lower operating risk and shipping cost.
  - No need to dehumidify or seal room
- Excellent material compatibility
- Cycle time < 15 minutes possible

Vaporized hydrogen peroxide (VHP)

- Hot vaporization
- Slow H_2O_2 distribution
- More H_2O_2 consumption
- Higher concentration H_2O_2 required
  - Higher operating risk and shipping cost.
  - Need to dehumidify and seal room
- Good material compatibility
- Cycle time < 2 hours possible

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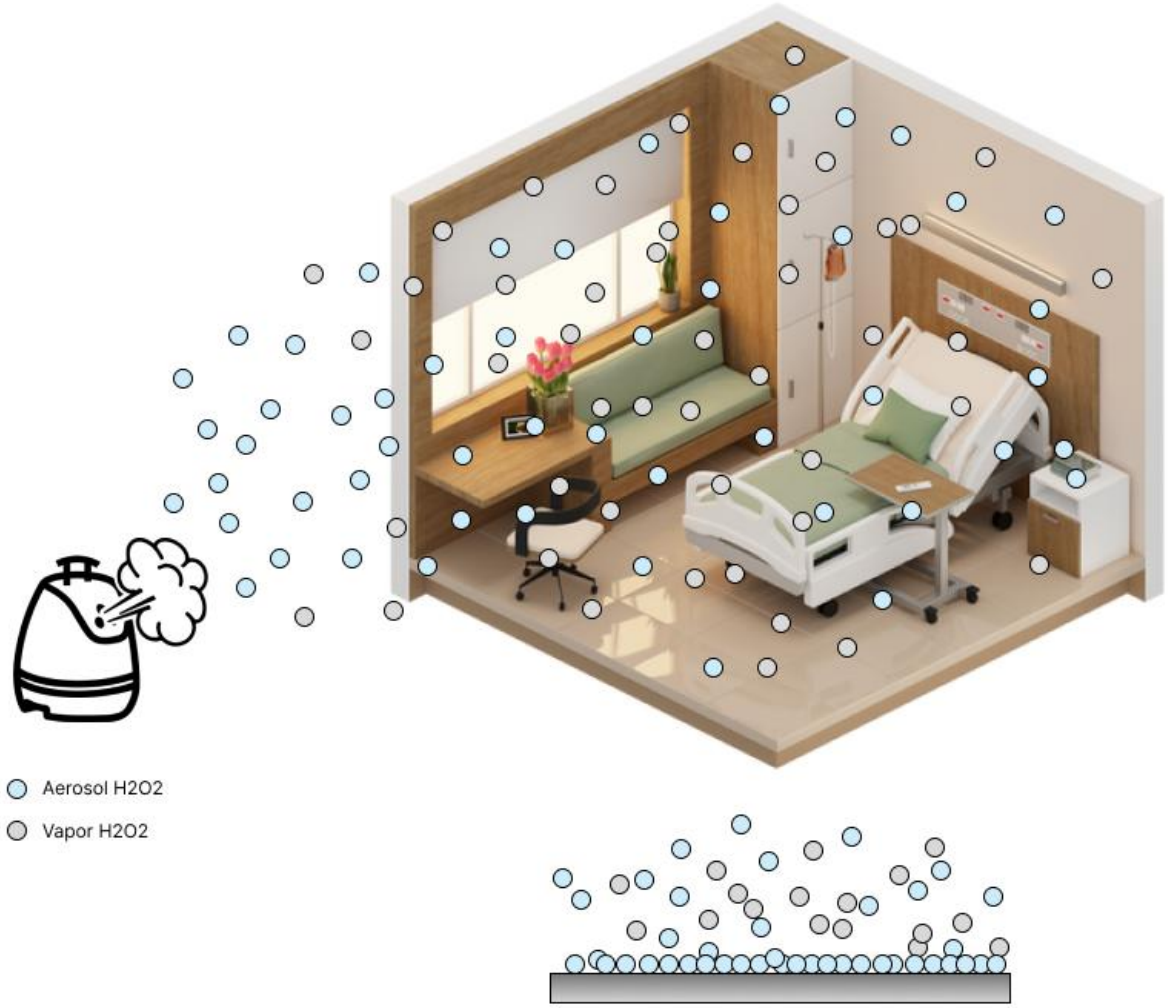
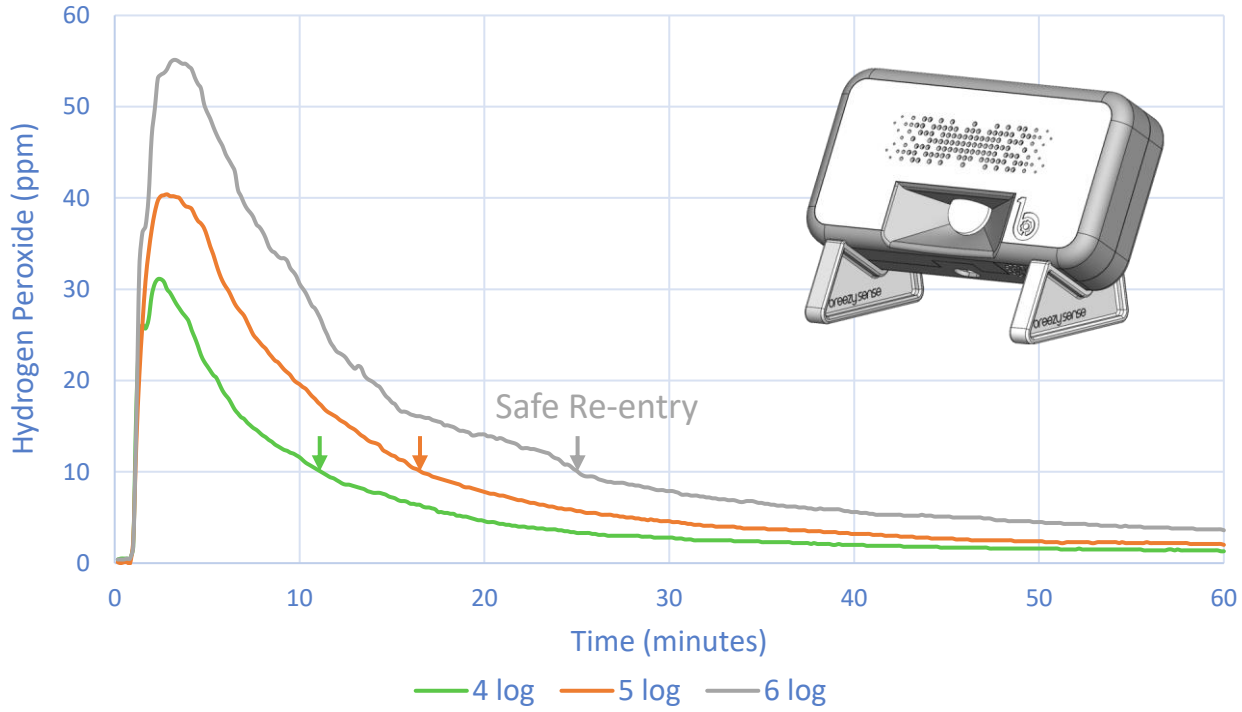
aHP disinfection methodology



- Aerosol H_2O_2 droplets rapidly fill a room in 30-120 seconds
- A mixture of H_2O_2 droplets, H_2O_2 vapor, Hydroxyl ions (OH-), and Hydroxyl radicals (·OH) interact with surfaces throughout the room
- After 10 minutes of contact time, there will be a 4-6 log reduction in pathogens
- After up to 20 minutes of evaporation time, the H_2O_2 completely transforms into H_2O and O_2

Aerosolize and distribute → Interact with Surfaces → Decay into water

Sensors measure H_2O_2 in real time



- Electro-chemical H_2O_2 sensors measure dosages for successful disinfection.
- Sensors also indicate when a room is ready for re-entry after disinfection.

H_2O_2 Safety Limits

- NIOSH: 75 ppm immediate exposure limit.
- OSHA: up to 1 ppm time-weighted average over an 8-hour period.

The Technology of Breezy Blue™

Our Goals

- No-touch disinfection
- High germicidal efficacy
- Whole-room coverage
- Simple to use
- Maintenance free
- Data logging for audits and QA
- **Bottom line = save time, money and lives**

Hospital Applications

1. **Isolation Terminal Clean**
(upon contagious patient discharge)

2. **Regular Deep Cleaning**
(sterile equipment rooms, operating rooms, shared restrooms, etc.)

3. **Transport/EMS**
(ambulances between patients or shifts)

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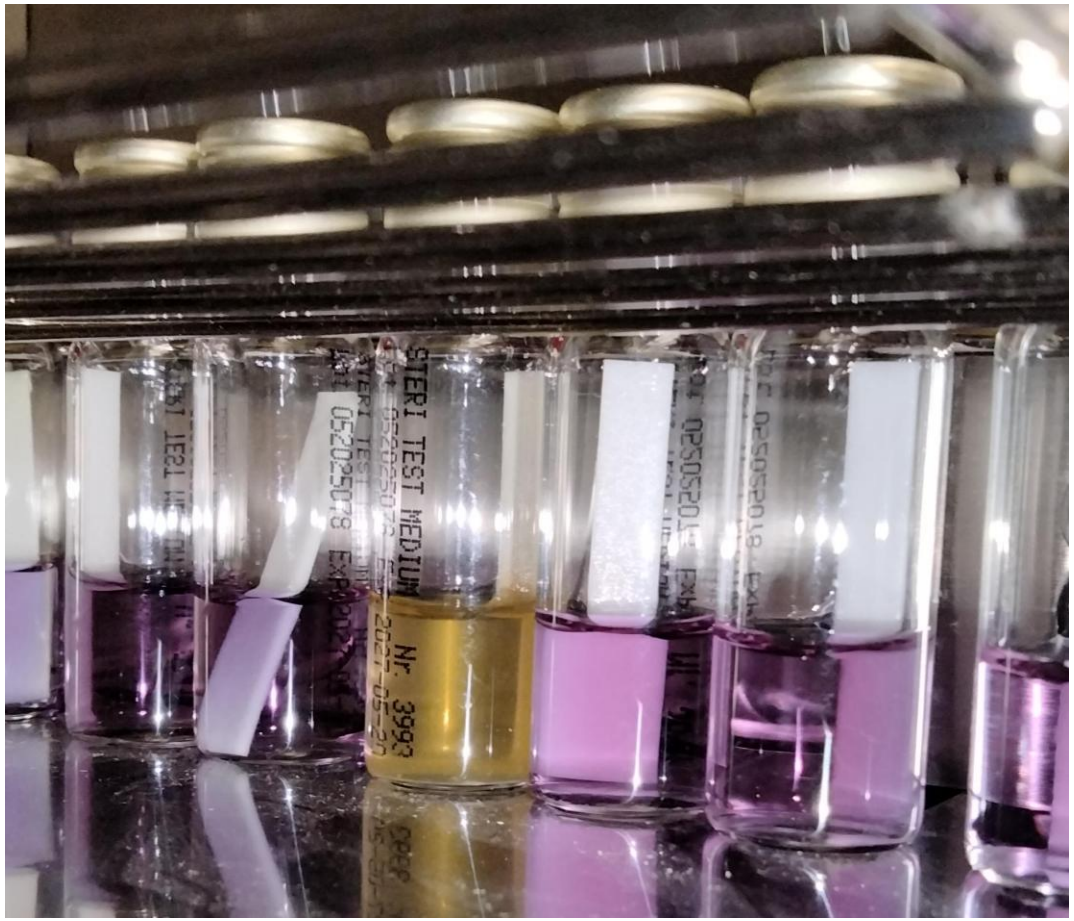
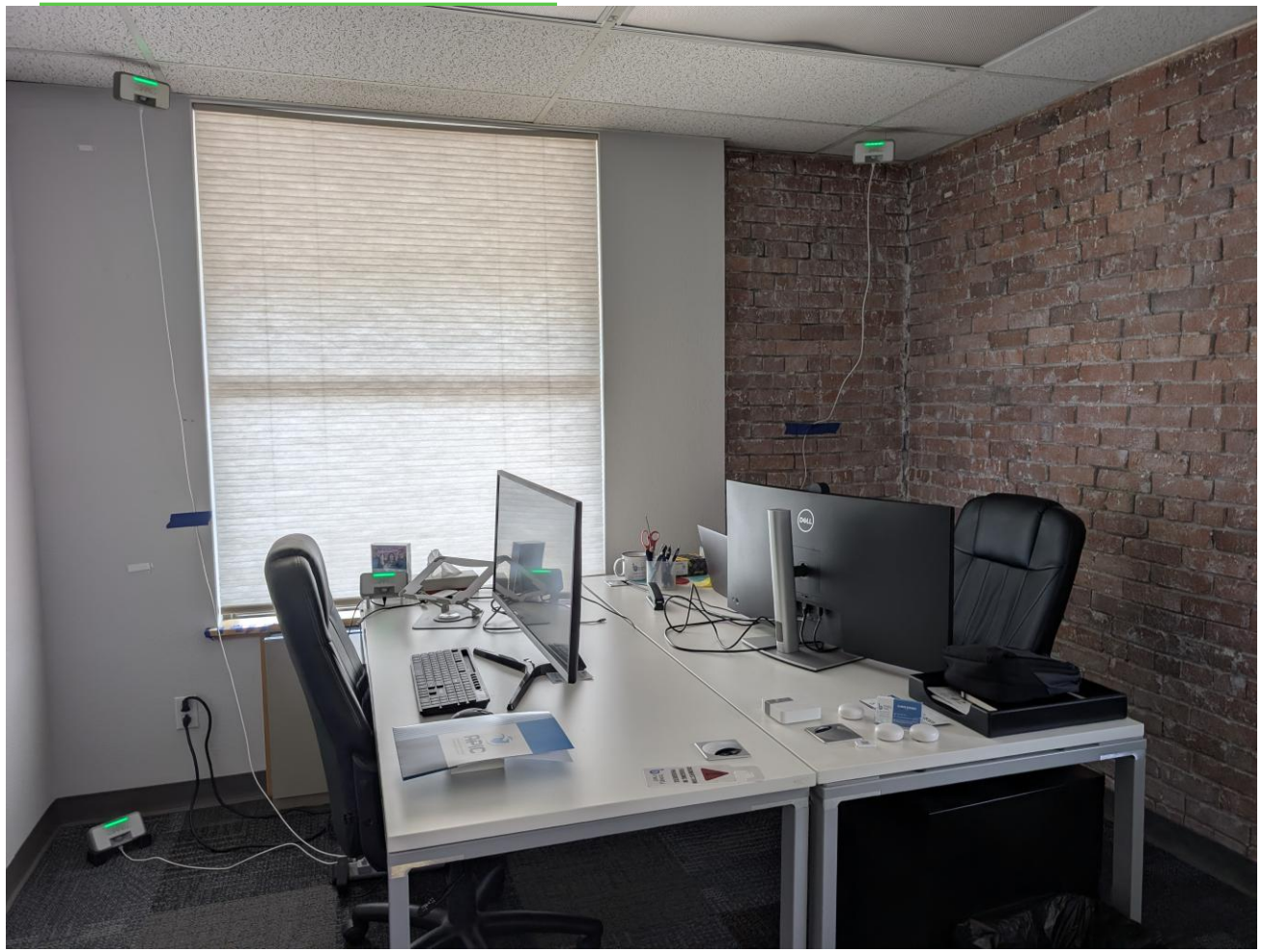
Clinical Data

Biological indicators



- *Bacillus atrophaeus* is an industrial bacteria used within Biological indicators (BIs) for validation of sterilization systems (FDA, 2007; Fritze & Pukall, 2001; Gibbons et al., 2011; Weber et al., 2003).
- *B. atrophaeus* is a spore forming bacteria that is difficult to kill and is known as a good proxy for a variety of infectious organisms including *C. difficile*.
- *B. atrophaeus* BIs with more than 10^4, 10^5, or 10^6 CFU per carrier are used to test for >4, >5, or >6 log pathogen reduction.
- If a single *B. atrophaeus* spore remains after the disinfection cycle, it will regrow within the growth medium during a 7-day incubation cycle, turning the medium from violet to yellow.

Biological & Chemical Indicator Testing



- Test H_2O_2 dosage over 10-minute contact time with chemical indicators (sensors).
- Measure 8-hour weighted average of H_2O_2 for re-entry time.
- Test germicidal efficacy with tiered BIs (4, 5, and 6 log).
- Test at multiple locations and heights throughout the room.

Third-Party Lab Testing & EPA Registration

Pathogen	Type
ANIMAL PATHOGENIC BACTERIA (G- AND G+)	Bacteria
ANIMAL PATHOGENIC FUNGI	Fungi
ASPERGILLUS NIGER	Fungi
ESCHERICHIA COLI	Bacteria
FELINE CALICIVIRUS	Virus
HUMAN IMMUNODEFICIENCY VIRUS (HIV-1)	Virus
INFLUENZA A (H1N1 & H5N1)	Virus
MOLD/MILDEW	Mold
NOROVIRUS	Virus
PSEUDOMONAS SPP.	Bacteria
RHINOVIRUS	Virus
SALMONELLA ENTRICA	Bacteria
SARS-CoV-2 (EPA List N for COVID-19)	Virus
STAPHYLOCOCCUS AUREUS & MRSA	Bacteria
SULFATE-REDUCING BACTERIA	Bacteria

Pathogens tested within third-party GLP laboratories and registered with the EPA for **Breezy HaloSpray™** disinfectant (registration #84526-1)

aHP Clinical Results

Case Study - Presbyterian Santa Fe Medical Center

- Presbyterian adopted Breezy Blue to assist with the deep disinfection of their Operating Rooms during nightly bio-decontamination starting in July 2023. Prior to adding Breezy Blue, surgical site infections (SSI) occurred every few months. Since adding Breezy Blue two years ago, there has been only one SSI in total.
- *"We have been using Breezy Blue as part of our disinfection protocols within our operating rooms for nearly two years,"* said Jessi Workman, Chief Nursing Executive of Presbyterian Santa Fe Medical Center. *"Our results have been outstanding, and we are now adding Breezy Blue to other departments."*

aHP Clinical Results

Case Study – reduction of *C. difficile* infections using aHP over a 10-year period

- The American Journal of Infection Control published this study that found that adding aHP to regular cleaning procedures significantly reduced *C. difficile* infection (CDI) rates in hospital settings.
- **Prior** to the implementation of aHP throughout a 475-bed hospital (July 2009 - September 2011), the facility recorded **120 hospital-acquired CDIs**.
- **After** the implementation of aHP (April 2012 - December 2014), only 72 cases were recorded. This is a **41% decrease in CDIs**, from 4.6 infections per 10,000 patient days to 2.7 per 10,000 patient days.
- The reduction increased over the **next few years**, and researchers found a **74% decrease in CDIs** between January 2015 and December 2019 after implementing aHP throughout the hospital.

Conclusion

- Surface spread HAIs are a challenge due to the long survival and fast regrowth of many pathogens.
- Hydrogen peroxide disinfectant is highly effective, generally safe, ecofriendly, noncorrosive, and leaves no residue.
- When aerosolized, H_2O_2 droplets spread throughout an entire room and disinfect as the droplets transform into H_2O and O_2.
- Dosages (fogging time) can be adjusted to balance pathogen log kill with room re-entry times.
- aHP has been demonstrated in multiple clinical studies to be one of the most effective methods to combat surface-spread HAIs.

Thank You!

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