Technical Report

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Subject: Purashield vs UV disinfection technology on air filtration of biological contaminants

Scope

To compare pros and cons of Purafil SP Media and Puraward, the active antimicrobial agents offered in Purashield air filtration, to UV disinfection technology on air filtration of biological contaminants.

Background

Air cleaners using Photocatalytic Oxidation

Photocatalytic oxidation (PCO) uses UV light to mediate redox reactions of gases and biological particles adsorbed on the solid surface of material or photocatalyst. The most common photocatalyst is TiO_2 (Titanium dioxide). When exposed to UV light, photocatalysts generate highly reactive oxygen species that react to adsorbed gases and biological particles. PCO light sources include UVA (400-315nm), UVC (280-200nm), and UV-V (<200nm). The efficiency of PCO varies depending on the contaminant and the system design from 0 to nearly 100%, with longer residence times needed to achieve higher (single-pass) efficiencies.

Air cleaners using Ultraviolet Germicidal Energy (UVGI)

Ultraviolet (UV-C) disinfection is used to degrade organic material and inactivate microorganisms. UV-C produces short wavelength light (or radiation) that can damage the genetic material in the nucleus of cells of microorganisms such as bacteria, viruses, and molds. The cells may be killed or made unable to reproduce. The most effective wavelength range is between 220 and 300nm, with peak effectiveness near 265nm. This system is not a filter. Inactive particles (i.e. dead fungal spores) may still cause a negative human response. UVGI systems may be installed inside HVAC systems, irradiate air near the ceiling, or be incorporated in a stand-alone air cleaner.

The effectiveness of UVGI depends on type of microbial contaminant, specific species, light intensity, exposure time, lamp distance and placement, lamp life cycle and cleanliness, air movement patterns, temperature, and relative humidity. Experience suggests that a moving air stream does not provide favorable killing rates because of the short exposure time. Airborne removal of biological contaminants is best applied for the irradiation of downstream coil surfaces to avoid fungal amplification on wet surfaces with continuous exposure to the UV. Under ideal conditions, inactivation and/or killing rates of 90% (single pass) or higher can be achieved.

Next Generation Far-UVC Lamp

UV light is dangerous to humans because it can penetrate the skin and cause cancer and cataracts. A narrow band of UV light (Far-UVC light) is safe for human exposure and still can kill airborne microorganism, including some types of coronavirus. Lamps using far-UVC light are currently in production and waiting for Food and Drug Administration approval. This can be applied to reduce the concentration of viruses in rooms where people are present and may cough or sneeze.

Testing

Proposed ASHRAE Standards 185.1 and 185.2-2014 provides methods of testing UV lights to inactivate airborne microorganisms in air handling units and in HVAC units, respectively.

Purafil SP Media

Purafil SP Media consists of generally spherical, porous pellets formed from a combination of activated alumina and other binders, suitably impregnated with 12%wt sodium permanganate ($NaMnO_4$). It has been specially engineered to provide the highest oxidation potential available, assuring the highest overall performance. Purafil SP Media demonstrates a high working capacity for broad-spectrum control in applications where multiple contaminants are present.

The active ingredient, $NaMnO_4$ has been used as a disinfectant to inactivate or destroy microorganisms, and is effective in fighting viruses. It also kills bacteria, fungi and algae. Sodium permanganate is one of the most widely used inorganic chemicals for the treatment of municipal drinking water and wastewater. Breakdown components of $NaMnO_4$ (sodium, manganese, and water) are common in nature.

Puraward

Puraward is a high efficiency fiber embedded with a proprietary technology to enact antimicrobial filtration. Engineered zeolitic substrates scaffolded on the surface of Puraward fibers provide a controlled release of copper and silver ions onto contacting microbes and particles. These ions synergistically attack airborne bacteria, viruses, and fungi upon contact. Puraward is amenable to single or multiple uses over long durations, making it ideal for use in air purification systems. Importantly, the impregnation procedure for Puraward prevents any leaching or off-gassing from the fibers, and the technology is non-hazardous. Efficacy data on a wide array of bacteria, viruses, and mold species support >99.9% removal of these microbial contaminants by Puraward alone.

Concerns with using UV systems

PCO technology,

- With increased air flow and insufficient residence time, and in the presence of halogenated compounds, oxidation may not complete and by-products (aldehydes, acids, etc.) are released as harmful airborne pollutants.
- Efficiency varies greatly from 0 to 100%.
- UV-C light is dangerous to humans. It can penetrate the skin and cause cancer and cataracts.

UVGI technology,

- Does not filter the air and inactivated particles remain in the air stream. Dead fungal spores and other particulates in ventilation systems may cause a negative human response. A prefilter and downstream particulate filtration is still recommended.
- A moving air stream does not provide favorable killing rates because of the short exposure time to the UV.
- Irradiation of downstream coil surfaces to control on fungal/bacterial amplification on wet surfaces is the ideal application. However, for virus in the air stream, UVGI is less efficient due to the short contact time with the UV.
- UV-C light is dangerous to humans. It can penetrate the skin and cause cancer and cataracts.

According to the EPA:

"If properly designed, ultraviolet germicidal irradiation (UVGI) cleaners that use ultraviolet radiation from UV lamps may destroy indoor biological pollutants such as viruses, bacteria, and some molds that are growing on the moist interiors of HVAC surfaces (e.g., cooling coils, drain pans, or ductwork). But typical UVGI cleaners used in homes have limited effectiveness in killing bacteria and molds. Effective destruction of some viruses and most mold and bacterial spores usually requires much higher UV exposure than is provided in a typical home unit. Furthermore, dead mold spores can still produce allergic reactions, so UVGI cleaners may not be effective in reducing allergy and asthma symptoms.

Comparative information is provided below to facilitate comparison between UVGI technologies and the active antimicrobial components of Purashield: Puraward and Purafil SP.

Antimicrobial Mechanism[1-4]

Purafil SP	Puraward	UV Irradiation
• Lysis of microbial lipid membranes through oxidation	• Copper ions degrade bacterial/fungal cell walls, facilitating intercellular transport of silver ions	• Mechanism sometimes referred to as Ultraviolet Germicidal Irradiation (UVGI)
• Oxidative destruction of bacterial protoplasm	• Prevents bacterial replication through DNA disruption	• UVC wavelengths are strongly adsorbed by nucleic acids within cells, which can cause defects in DNA replication and suppress action of necessary proteins within microorganism
• Inhibits procreation of microbial life	• Disrupts enzymatic processes in cellular respiration and intercellular transport in bacteria	• Generated free radical species (e.g. $OH^{\cdot}$), which oxidatively degrade airborne microbes (similar end results as Purafil SP oxidation on viruses/bacteria/fungi).
• Does not sustain microbial life	• Decreased pH on the fiber surface irreversibly alters viral exterior and binds proteins to inactivate viruses	• Average bacterium can be killed in 10s of exposure to UVGI at a distance of 6in from the lamp
• Can disrupt cellular transport		

Limitations[2-5]

Purafil SP	Puraward	UV Irradiation
• Requires contact between permanganate and microbial contaminant	• Requires contact between Puraward fiber and microbial contaminant	• Requires UVC (200-280nm)
• Requires multiple turnovers of air volume to effectively contact airborne contaminants	• Requires multiple turnovers of air volume to effectively contact airborne contaminants	• Requires multiple turnovers of air volume to effectively contact airborne contaminants
• Requires changeout of spent media (operational cost)	• Requires changeout of spent media (operational cost)	• Requires sufficient exposure time to light for reactive oxidation—one "contact" will not destroy viruses/bacteria
	• Final form is limited to filter	• UVC exposure is hazardous to human health
		• High upfront (capital) cost ($100s-$1000s) for UVC lamp only
		• Not disinfecting against all pathogens (e.g. *C. difficile*)[5]
		• UV radiation is not very penetrating. So blockage of light can inhibit sterilization (e.g. airborne particulates, blockage in air filter design, etc.)

Delivery Mechanism[2-4]

Purafil SP	Puraward	UV Irradiation
• Pelletized media	• Engineered fibers	• Air purifiers
• Standalone pouches	• Rolled goods	• Mercury-based lamps
• Air purifier	• Air purifier	• Ultraviolet light-emitting diodes (UVC LED)
• Embedded in filter		• Pulsed-xenon lamps

References

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2) *Ozone: Science & Engineering*. **9** (4): 299–313.
3) *American Journal of Infection Control*. **2015**, *10*(43), 61-66
4) Kowalski. Ultraviolet Germicidal Irradiation Handbook. **2009**. DOI 10.1007/978-3-642-01999-9
5) C. diff Contamination Not Affected by Ultraviolet Disinfection Devices. *Infection Control Today* **2020**, *24*