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Examination of Residual Silver and Potential Implications for Laboratory Safety

Synopsis

Material compatibility testing was performed exposing samples of four different facility construction materials to 12 repeated cycles (380 minutes total) with an aerosolized disinfection solution (5% H_2O_2 & 0.01% silver). Following 12 cycles, both the samples and sample table displayed visible particulate residue. Observed results and potential implications for facilities are reviewed here.

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Introduction

An ideal environment for specialized laboratory work would be one that could be maintained in a sterile state. With over a trillion types of microbes on earth, their ubiquitous presence makes achieving environmental sterility a temporary state at best. Biodecontamination within a laboratory or its equipment is the modern solution to achieving the necessary sterile state. In an attempt to prolong the benefits of biodecontamination, some industry manufacturers add silver, a known biostat, to their chemical solutions. While this may seem an ideal answer to prolonging the decontaminated state, the effects of residual silver have known negative consequences that should be considered. Silver is a metal which does not break down and therefore persists in the environment in which it is introduced. The implications to the environment in which it is introduced should be well understood.

Silver has a long history of medical use due to its toxicity to pathogens; however, silver is also toxic to healthy cells and can be permanently retained once in the body.[1] This dynamic has implications not only for human exposure, but for the exposure of laboratory animals as well. Silver nanoparticles can disrupt cellular membrane integrity, influence cell metabolism, and lead to genetic changes. Silver accumulation within an organism can be transported in the bloodstream and have a toxic effect on all tissue types. At high levels of saturation, this can lead to impaired organ function disrupting endocrine and reproductive systems, as well as changing cognitive function and behavioral habits.[2] *With these known effects, researchers working with cell and gene therapy or laboratory animal research, especially animals with modified immunological profiles, should be aware of the potential effects silver could have on their research*.

Beginning in 2012, the addition of silver in consumer products has been regulated by the European Union due, not only to the potential health effects, but to the potential environmental impact as well.[3] Likewise, in the US, the EPA has issued documents cautioning against the use of silver, in part due to the potential to severely impact aquatic environments.[4] As an element, silver is classified as a persistent and toxic pollutant to humans and the environment.[5]

Of particular interest to laboratory facilities and the decontamination industry, silver nanoparticles have demonstrated chemical interactions with surfactant-based surface cleaners. Interaction with cleaning chemicals can decrease the intended antimicrobial effects and when removed can lead to silver contamination of wastewater and a multitude of negative downstream effects.[6]

In view of these known dynamics and concerns associated with silver use, any potential benefit of use must be weighed carefully against concerns for research integrity, as well as health and environmental impacts. As part of a series of material examinations designed to enhance understanding of the interplay between biodecontamination and the laboratory environment, CURIS studied the repeated exposure of material samples to a hydrogen peroxide (H_2O_2) chemical formulation containing silver (Ag) nanoparticles and documented the findings.

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Materials

H_2O_2 delivery device (Sanosil, New Castle, DE)
5% H_2O_2 / 0.01% Ag disinfectant solution (HaloMist EPA No. 845266, Halosil International, DE)
Test chamber (CURIS Labs, Oviedo, FL)
Engineered polymer wall and ceiling material sample
90% Quartz tile material sample
93% Quartz tile material sample
Acrylic worktop material sample

Methods

Testing took place in a test chamber designed for studying aerosolized and gaseous decontamination. Material samples were placed on a standard height plastic table within the test chamber. Material samples were exposed to 12 repeated decontamination cycles with 5% H_2O_2 / 0.01% Ag decontamination for a total of 380 minutes of exposure. Cycles consisted of dehumidification to ≤50% RH, injection of the aerosolized chemical solution (dose concentration 0.011 oz/ft^3), and chemical dwell time. Following the decontamination, the test chamber was left unopened overnight as recommended by the manufacturer for safety and efficacy. Further aeration was necessary to reach safe levels of 0.2 PPM, the recommended levels of reentry for this technology.[7]

Samples were not cleaned between repeated cycles. Following exposure, samples were observed for any material changes or residues and photographic results recorded. At the completion of testing, selected samples were wiped with 70% isopropyl alcohol and photographed to show the particulate residue (Image 1).

Image 1. Material sample following 380 total exposure minutes. Left side of image is the untouched sample; right side of sample has been wiped with 70% isopropyl alcohol for comparison. Particulate residue is visible to the naked eye.

Results

All testing took place inside a clean and sealed test chamber. Following 12 cycles, all samples were covered in a gray particulate visible to the naked eye (Image 1).

Of note, the plastic sample rack within the test chamber was also noticeably covered in a dust-like particulate following 12 exposure cycles (Image 2). This may be attributed to residual negative static charge of the plastic material. As plastics are poor conductors, they do not easily dissipate static charge on their surface which in turn attracts particles, particularly positively charged particles such as silver ions.

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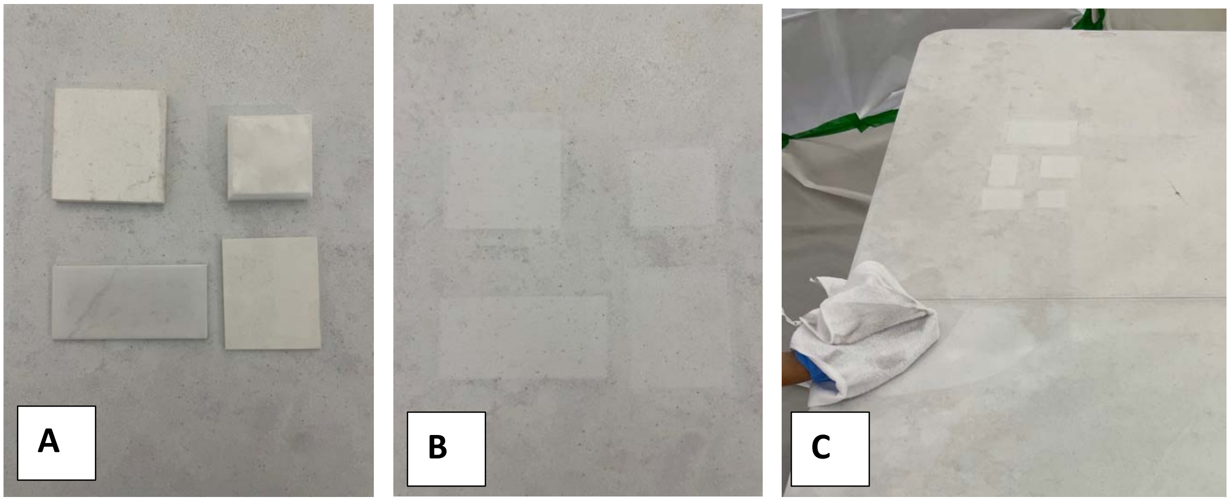

Image 2A-C. A) Picture of sample materials post cumulative treatments. B) Plastic tabletop where sample materials were placed during the decontamination cycle. With samples removed, four rectangular outlines of particulate-free area under the tested materials can be seen. C) A wider image of the table showing a cleaned area and the visible residue deposited on a cleaning cloth.

Image 3. The H_2O_2 delivery device used for testing. This device is paired for use with the hydrogen peroxide and silver (5% H_2O_2 / 0.01% Ag) disinfectant solution.[7]

Conclusion

Silver nanoparticles are widely used in commercial applications across numerous industries. In a laboratory setting, previous studies have examined the interaction of nanosilver with common cleaning chemistries[6] and documented in vivo silver accumulation and its effects in laboratory mice.[2] This material compatibility study looked at the repeated use of a common decontamination chemistry and its impact on material surfaces, finding a particulate residue throughout the test chamber following 12 cycles totaling 380 minutes of exposure.

Although standard operation for decontamination procedures calls for dissipation of the employed chemical prior to safe reoccupation and use of the treated space, this practice does not take into account residues which may be left behind. While nanosilver may be an effective biostat for existing contamination, its indiscriminate nature could have serious consequences in facilities performing cell and gene therapy, and in animal research facilities of all kinds.

Silver nanoparticles used as a biocide in water systems have demonstrated galvanic deposition on stainless steel surfaces, both decreasing the availability of active silver and coating the stainless steel surfaces.[8] Although some silver particles are not nanosilver, aerosolized decontamination distributing silver ions may display similar behavior both in coating stainless steel equipment surfaces and in decreased function of the silver itself. Laboratories needing a residue-free environment may incur additional expenses and labor in removing particulate residue that has been distributed throughout a laboratory and on laboratory equipment.

Where residual silver is a desired component of decontamination practices for its antimicrobial properties, a dichotomy exists. Smaller particle sizes of silver are more toxic relative to larger particles due to the higher surface area per volume,[5,6] thus smaller particles are more desirable for antimicrobial uses. However, while larger particles settle out of the air within minutes, silver nanoparticles may remain suspended at length, influenced by factors of air movement, air exchanges, etc.[5] This dynamic would indicate that the most active silver particles pose concerns for inhalation (by staff or laboratory animals) while not providing the expected surface antimicrobial action.

With a growing understanding of the potential impacts to health and the environment, practices which leave silver residues should be carefully reviewed. Additionally pertaining to the necessity of a controlled environment for the integrity of research, laboratories conducting cell culture, tissue research, or animal studies, including inside vivariums, must carefully consider the potential effects, beyond decontamination, that some chemistries may cause.

> “ Amara’s law may apply to the effects of nanotechnology. The law is, “We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run.” The short-term benefits of [Nanoparticle silvers] and their anti- microbial properties might be overestimated, but their long-term effects might be underestimated.
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> ~ Quadros & Marr[5] in *Environmental and Human Health Risks of Aerosolized Silver Nanoparticles*

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