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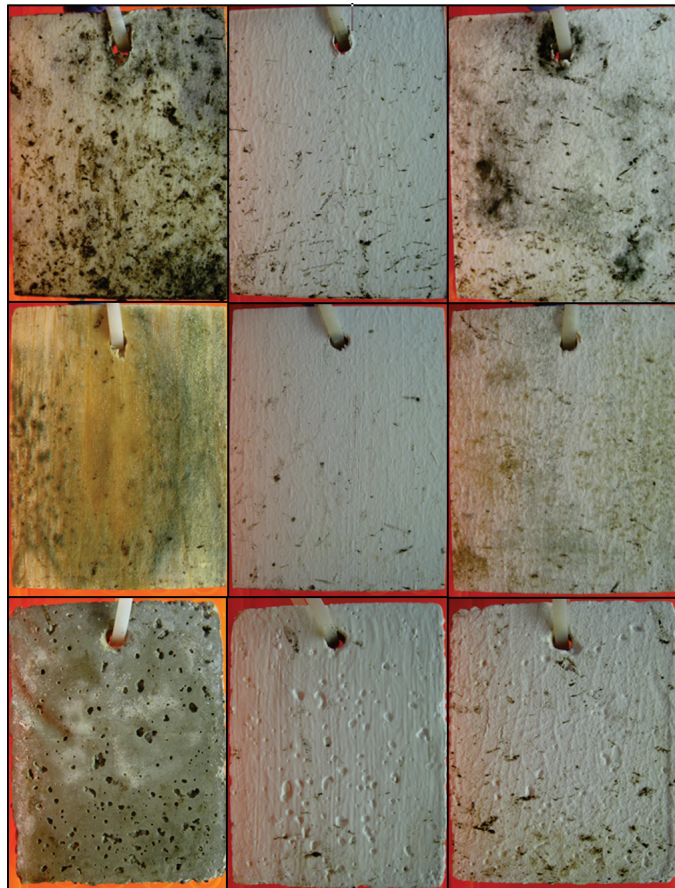
Resilient and Sustainable Coatings

Comparison of Antifungal Efficiencies of Photocatalytic and Antimicrobial- Infused Coatings

Evaluation of Five Antimicrobial Coatings Using Standard Test Methods

Clint M. Arnett, Rebekah C. Wilson, and Kathryn A. Guy

August 2020



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Comparison of Antifungal Efficiencies of Photocatalytic and Antimicrobial- Infused Coatings

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Abstract

New buildings are being constructed and existing buildings retrofitted to be more energy efficient to meet increasingly stringent Department of Defense (DoD) energy standards. Although these standards save energy and lower operational costs, they also limit fresh air within a structure and can cause a buildup of harmful substances in indoor environments. Of particular concern are molds, which can put building occupants at risk and damage infrastructure. One possible solution to this increasing Army problem is to coat building materials with photocatalytic paints, which have the ability to both destroy microorganisms as well as the toxic byproducts they produce. This work compared two next-generation photocatalytic coatings against three more traditional antimicrobial-infused coatings for their ability to resist fungal contamination using three accelerated test conditions. Under each test condition the photocatalytic coatings were found to perform poorly compared to the antimicrobial-infused coatings. Moreover, the control coating, which contained no active antimicrobial (standard latex paint), performed as well as or better than all the antimicrobial coatings tested. This suggested that there may be little benefit to using antimicrobial coatings to inhibit fungal colonization over a standard latex paint; however, further testing is required to confirm this perception.

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Preface

This study was conducted as part of a congressional add titled “Environmentally Friendly and Sustainable Coatings for Military Structures.” The Program Manager was Dr. Rebekah C. Wilson, CF-M; and the technical monitor was Mr. Kurt J. Kinnevan, Lead Technical Director Installations.

The work was performed by the Environmental Processes Branch of the Installations Division, U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Mr. Jeffrey A. Burkhalter was Chief of the Environmental Processes Branch and Ms. Giselle Rodriguez was Acting Chief of the Installations Division. The Acting Deputy Director of ERDC-CERL was Ms. Michelle J. Hanson and the Acting Director was Dr. Kirankumar V. Topudurti.

This research was supported in part by appointments at the Research Participation Program administered by the Oak Ridge Institute for Science and Education (ORISE) through a cooperative agreement between the U.S. Department of Energy and the U.S. Army Construction Engineering Research Laboratory. The authors would like to give special thanks to Mr. Joshua Petit for his valuable contributions to this study as a North Carolina Agricultural and Technical State University Student and ORISE appointee during the summer of 2019.

COL Teresa A. Schlosser was Commander of ERDC, and Dr. David W. Pittman was the Director.

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1 Introduction

1.1 Background

After the oil embargo of the 1970s, which caused energy processes to spike, buildings were designed or retrofitted with tighter, more efficient envelopes. As a result, the average ventilation standards decreased from 15 cubic feet per minute (CFM) of outside air per building occupant to 5 CFM. Although these changes increased the energy efficiency of the structures, the resulting lack of outdoor air and continued recirculation of interior air led to a significant decrease in indoor air quality according to the U.S. Environmental Protection Agency (USEPA) (1991). Poor indoor air quality can contribute to a phenomenon known as “sick building syndrome,” which refers to a situation in which the occupants of a specific building experience acute health- or comfort-related effects that seem to be linked directly to the time spent in the building. Signs of sick building syndrome include headache, irritation of the eyes, nose and throat, fatigue, and lack of concentration (Ghaffarianhoseini et al. 2018, Joshi 2008). Mold is a major contributor to sick building syndrome, partly as a result of the spores they produce but also due to the volatile organic compounds (VOCs) they emit (Straus 2009, 2011). For example, 1-octen-3-ol is a ubiquitous fungal VOC responsible for the musty odor associated with mold contaminated environments. In the volatile phase, 1-octen-3-ol has been shown to be 80 times more toxic than toluene (Bennet and Inamdar 2015). In fact, indoor air can be up to 100 times more polluted than outdoor air due in part to microbial contamination and VOC production (USEPA 1991).

Mold is found in almost all indoor environments and because of the severe adverse health effects it can cause, the fungus is quickly becoming considered “the asbestos of the 21st century.” Mold can proliferate on nearly any substrate and in addition to contributing significantly to poor indoor air quality, it can cause unsightly defacement and costly infrastructure damage (Arumala 2007). In fact, the USEPA (1991) estimates that up to 50% of all illnesses are related to indoor air pollution. Sick building syndrome results in losses of over \$70 billion annually in the form of decreased productivity, increased healthcare cost, and increased sick leave (Srecec et al. 2005).

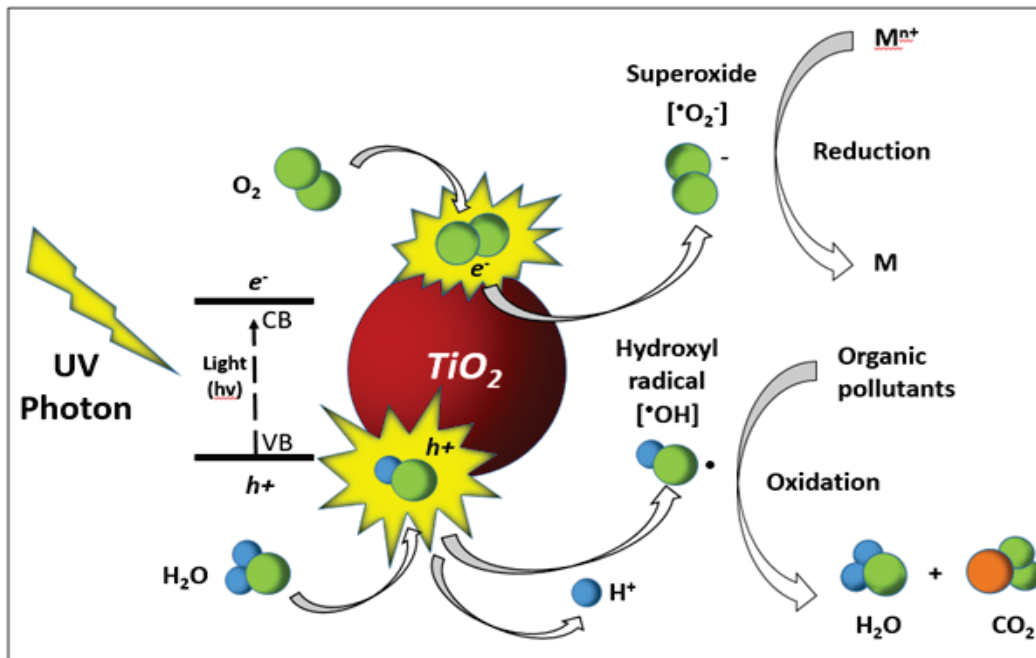
This problem is not restricted to the private sector but has also become a major issue on Army installations. Studies have revealed extensive mold

contamination in Army barracks buildings, most notably in and around heating and cooling vents, shower stalls, and closets (Stephenson et al. 2011). Furthermore, the DoD Inspector General has stated that there is a significant presence of mold on DoD facilities around the world, which places unnecessary risks on both the warfighter and their families (DoD OIG 2016). More recently, testimony on military housing at the Senate Armed Services Committee revealed widespread mold contamination on bases across the country (C-Span 2019). Additionally, mold proliferation can be especially problematic in the often austere conditions of contingency basing; this can increase health risks to Soldiers and compromise readiness and ultimately the mission. One possible solution to this growing Army problem is to use novel coating formulations that have both antimicrobial and pollutant destroying properties. Such coatings have great potential to reduce facility maintenance costs while simultaneously increasing the quality of life on Army installations and in contingency basing environments.

Numerous biocide-based coatings have been marketed over recent years to combat mold proliferation. However, most commercially available antimicrobial paints are infused with poisonous chemicals that have the potential to harm humans, wildlife, and the environment (Perkins+Will 2017). Additionally, reactivity and overall biocidal effectiveness tend to be temporally limited. To address these issues, a new class of advanced catalytic coatings has been developed and introduced, mainly in foreign markets (Nanocoatings 2014). These next-generation coatings are formulated with catalytic titanium dioxide (TiO_2) that are nontoxic, environmentally friendly, easy to apply, and have the potential to remain active indefinitely in the presence of light in common indoor environments.

In the presence of water vapor and oxygen from the atmosphere, and light (315 – 400 nm) from natural or artificial sources, surfaces coated with catalytic TiO_2 can form strong oxidants (Figure 1). The radicals formed by the reaction are primarily hydroxyl ($\cdot\text{OH}$) and superoxide ($\cdot\text{O}_2^-$), which can both effectively destroy organic contaminants, including microorganisms and VOCs (Byrne et al. 2015, Desai and Kowshik 2009, Huang et al. 2016). The oxidation process mineralizes contaminants to harmless water and carbon dioxide to effectively decontaminate and sterilize the coated surface and the surrounding air. The TiO_2 catalyst is stable; therefore, the reaction can proceed indefinitely in the presence of near ultraviolet A (UV-A) light and atmospheric oxygen and water vapor. Coating formulations that have such photocatalytic activity therefore possess great potential to serve as fungal inhibitors for Army use.

Figure 1. Titanium dioxide mediated photocatalytic oxidation-reduction of pollutants via the production of hydroxyl and superoxide radicals from water and oxygen in the presence of light. Organic pollutants are mineralized to water and carbon dioxide.



Although catalytic TiO_2 has been shown to exhibit antimicrobial and pollutant destroying capabilities, its effectiveness within coatings has not been sufficiently evaluated to validate many manufacture's claims (Yadav et al. 2016, Truffier-Boutry et al. 2017). This work was undertaken to evaluate two next-generation photocatalytic coatings by comparing them against three more traditional antimicrobial-infused coatings for their ability to resist fungal contamination under three accelerated test conditions.

1.2 Objectives

The immediate objective of this study was to compare the antifungal efficiencies of two photocatalytic coatings against three chemically infused coatings in an effort to better determine their suitability for possible Army applications using a combination of two American Society for Testing and Materials (ASTM) and two International Organization for Standardization (ISO) test methods. A long-term objective of this work was to provide results that can help shape future guidance that will increase the quality of life and lower operational burdens on Army installations and contingency bases.

1.3 Approach

This study tested two commercially available photocatalytic and three antimicrobial-infused coatings and compared them for their ability to resist surface fungal colonization on wood, gypsum, and concrete substrates using ASTM D3273, *Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber* (ASTM 2016). To further evaluate each coating, ASTM 5590, *Standard Test Method for Determining the Resistance of Paint Films and Related Coatings to Fungal Defacement by Accelerated Four-Week Agar Plate Assay* (ASTM 2017) was used to determine each coating's resistance to fungal colonization. Coatings that contained catalytic TiO₂ were further tested to determine activity against mold spores and their ability to reduce methylene blue using ISO-13125, *Test Method for Antifungal Activity of Semiconducting Photocatalytic Materials* (ISO 2013) and ISO-10678:2010, *Determination of Photocatalytic Activity of Surfaces in an Aqueous Medium by Degradation of Methylene Blue* (ISO 2010), respectively. Effectiveness of each of the photocatalytic TiO₂ infused coatings were compared to three commercially available coatings infused with antimicrobial compounds and a standard latex paint with no antimicrobials to determine their suitability to control or eliminate fungal defacement.

1.4 Mode of technology transfer

The results of this work will directly support U.S. Army Strategy for the Environment in providing sustainability across the Army that will enhance human health, safety, and wellbeing, and also reduce cost and minimize impacts. This work also meets the requirements stated in Army Regulation (AR) 420-1, *Army Facilities Management*, Chapter 3, "Housing Management" (HQDA 2012), which requires a risk assessment, controls, and abatement of any health hazards to occupants to ensure safety.

2 Materials and Methods

2.1 Coatings used in this study

Two photocatalytic and three antimicrobial-infused coatings were evaluated for their ability to resist fungal contamination. The two photocatalytic coatings tested were Ecoreflex and Ecosil-ME. Ecoreflex is an interior/exterior, self-cleaning, water-based acrylic, photocatalytic coating manufactured by Diasen (Sassoferrato, Italy). The manufacture claims that, in the presence of artificial or natural UV-A, the coating can safely degrade several classes of nitrogen and sulfur-based pollutants as well as break down VOCs and inhibit bacteria and viruses on and above the coating surface. Additionally, Ecoreflex possesses reflective properties that can reduce solar heat absorption resulting in a net reduction in energy cooling costs, which could add operational benefits for military use. Ecosil-ME is a self-cleaning, interior, silicate coating manufactured by KEIM (Charlotte, NC). The manufacture claims that the coating creates a highly vapor permeable microporous coating that can destroy air pollutants and pathogens that come into contact the coating surface, ultimately purifying and disinfecting the surface to help maintain a healthy indoor environment.

Antimicrobial-infused coatings tested were Aftershock, Zinsser Mold-Killing Primer, and Sporicidin. AfterShock is a fungicidal acrylic sealant produced by Fiberlock Technologies (Andover, MA). The coating is designed to kill surface mold and inhibit future growth and spread in both residential and industrial applications. The coating is infused with both chlorothalonil and methylchloroisothiazolinone, which give the coating its antibacterial and antifungal properties. Zinsser Mold-Killing Primer is manufactured by the Rust-Oleum® Corporation (Vernon Hills, IL). The primer is intended for both interior and exterior use in residential, commercial, and industrial settings. The coating is infused with 3-iodo-2-propynyl butylcarbamate, an antifungal compound that has been used extensively as a preservative in personal care products for decades. The manufacture claims the primer can be used over existing mold and bacterial to inactivate it and control future proliferation. Of all the coatings tested, Zinsser Mold-Killing Primer is the most readily available and can be purchased at most home improvement stores. Sporicidin is a mold resistant coating produced by Contec (Spartanburg, SC). The manufacture claims the coating prevents growth of mold on the coating film by forming a dehydration finish that prevents moisture penetration and thus mold growth on the coating. In addition, the coating

contains a proprietary USEPA registered antimicrobial ingredient that is marketed to prevent mold and mildew growth on the film surface.

Sherwin Williams SuperPaint (Cleveland, OH), an exterior latex paint that is neither photocatalytic nor antimicrobial-infused, served as the control coating for test methods ASTM D3273 and ASTM 5590. The manufacture claims that properly coated surfaces are resistant to dirt and stains. Table 1 lists and briefly describes coatings used in this study. Appendix A includes product Data Sheets and Safety Data Sheets for coatings used in this evaluation.

Table 1. Description of antimicrobial coatings evaluated. Product data sheets for each coating evaluated can be found in Appendix A.

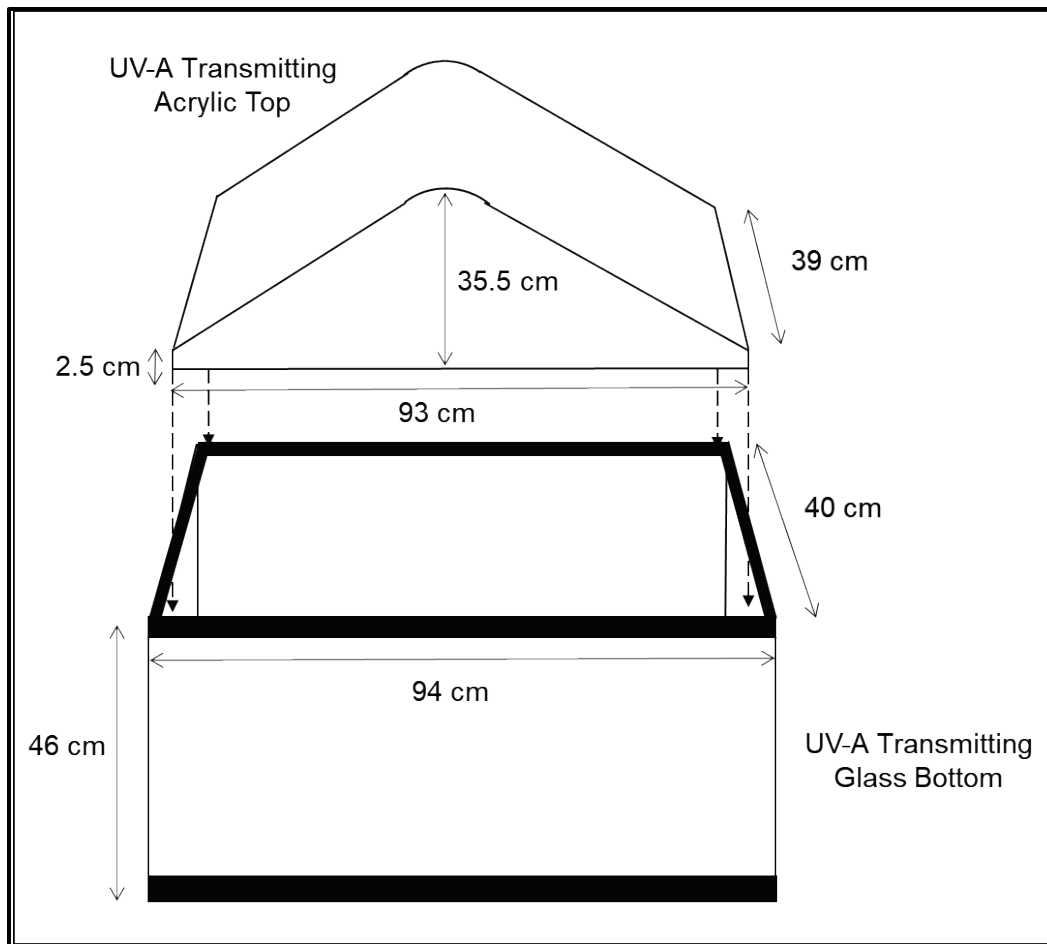
Coating (product #)*	Description	Manufacture	Product claims
Ecoreflex	Interior/exterior photocatalytic infused elastomeric acrylic	Diasen	Air-purifying and deodorizing, antibacterial, antiviral, prevents biological growth
Ecosil-ME	Interior photocatalytic infused potassium silicate mineral	KEIM	Destroys air pollutants and pathogens coming into contact with the surface and purifies and disinfects surfaces
AfterShock (8390)	Interior antimicrobial-infused acrylic sealant	Fiberlock	Kills residual mold and mildew and inhibits the future growth
Zinsser Mold-Killing Primer (276049)	Interior/exterior antimicrobial-infused styrene acrylic	Rust-Oleum	USEPA registered antimicrobial that prevents the growth of fungal organisms
Sporicidin (MRC-100)	Interior/exterior antimicrobial-infused nano-sealant	Contec	USEPA registered antimicrobial that prevents the growth of mold
SuperPaint (A89W1151)	Exterior acrylic latex no antimicrobial	Sherwin Williams	Stain resistant, washable

*Product number listed if available from the manufacture.

2.2 Evaluation of coating resistance to mold colonization in an environmental chamber (ASTM D3273)

ASTM D3273 was used to determine the relative resistance of the paint films to surface mold. Temperature-controlled environmental chambers were used to accelerate fungal growth conditions; this allowed the testing of all coatings on the three different substrates in approximately 3 months. Two custom environmental chambers were constructed with glass bodies and UV-A transmitting acrylic hoods (Figure 2). Polyvinyl chloride (PVC) trays with stainless steel grids and fiberglass mesh bottoms were fabricated to hold 4 cm of commercially available greenhouse soil 4 cm above 4 cm of diH₂O.

Figure 2. Schematic of custom environmental growth chambers, which were fabricated to test coatings on gypsum, wood, and concrete per ASTM D3273 standard test method.



Test coupons were suspended from carbon fiber rods with zip-tie fasteners equally spaced 8 cm from the soil. The chambers were designed to hold a total of 31 coupons spaced 8 cm from one another. Chambers were maintained at $95 \pm 3\%$ relative humidity and $32.5 \pm 1^\circ\text{C}$ using a 300W submersible heater. The exterior sides of the glass of the chamber to be irradiated with UV-A were wrapped with aluminum foil to increase reflectiveness and therefore light exposure on the coupons' surfaces. Additionally, the sides and bottoms of both chambers were insulated with 1.27 cm foam board to maintain consistent temperature and relative humidity over the course of each experiment. Temperature and humidity were tracked continuously using a traceable hygrometer/thermometer throughout each experiment.

Test panels measuring 1 cm thick by 8 x 10 cm were fabricated from pine, gypsum, and regular concrete. Uncoated panels of each substrate served as controls, as well as panels coated with standard exterior latex paint (SuperPaint), which did not contain antimicrobial or catalytic properties. Two

coats of each test material were applied with a low-nap roller to all sides of the clean panels. Panels were allowed to dry 48 hrs between coats and 4 weeks before use. Each coating was tested in triplicate on each of the three substrates. All coatings were tested on one substrate simultaneously within the environmental chambers. Mold species used for testing were purchased from the American Type Culture Collection (ATCC, Manassas, VA). Each substrate was evaluated individually by hanging the panels over soil inoculated with *Aureobasidium pullulans* (ATTC #9348), *Aspergillus niger* (ATTC #9142), and *Penicillium citrinum* (ATTC #9849) spores per the ASTM D3273 test standard. After inoculation, each environmental chamber was allowed to equilibrate for 4 weeks, then five potato dextrose (PDA) plates were placed in each chamber approximately 30 cm from the soil surface for 1 hour then incubated at 32.5 °C for 7 days. After incubation, plates were evaluated for fungal contamination. Additionally, uncoated gypsum coupons were introduced to the chambers, allowed to incubate for 4 weeks, and were then assessed for fungal growth using ASTM D3274, *Standard Test Method for Evaluating Degree of Surface Disfigurement of Paint Film by Fungal or Algal Growth, or Soil and Dirt Accumulation*, to ensure proper conditioning of the chamber before evaluating the coatings listed in Table 1.

Each coating substrate combination was exposed to UV-A irradiation at 1.0 mW/cm² for 3 hours per day and compared to coupons left in the dark. A 20W, blacklight blue (BLB) lamp, with a peak wavelength of 365 nm was used for this test method. Light intensity was monitored with an Analytik Jena UVX radiometer with a UVX-36 probe (Analytik Jena U.S., Upland, CA). Front and back surfaces were imaged using a digital camera before introduction into the chambers and then at 1-week intervals thereafter. The susceptibility of the coated surfaces to fungal growth were evaluated using ASTM D3274 over a 4- to 6-week period. ImageJ software was used to semi-quantitate the percent disfigurement (Abramoff et al. 2004, Rasband 2018). Both sides of each of the three replicates were measured and averaged (n=6). The percentages obtained were used to rate defacement according to the ASTM scale of 0 to 10 where 10 represents no fungal growth and 0 represents complete coverage (Table 2). Comparisons between each of the coatings were made, then they were ranked for their ability to resist fungal contamination using this rating scale.

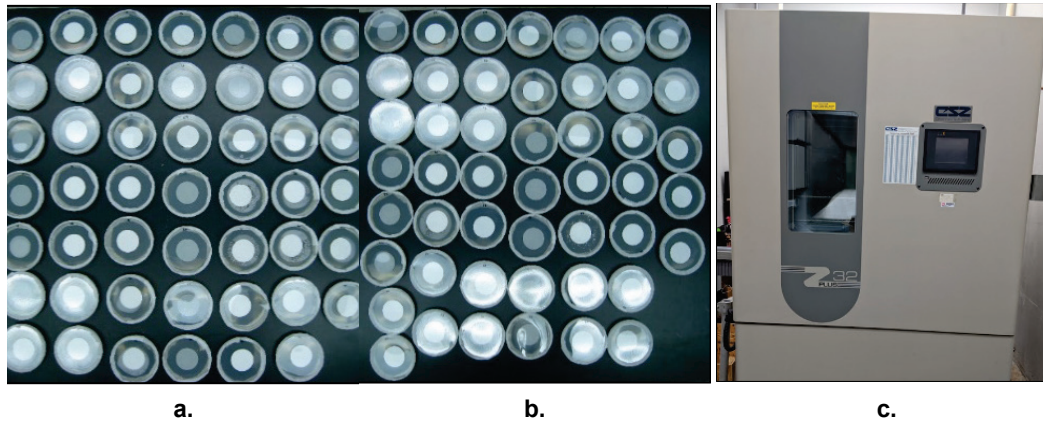
Table 2. ASTM D3273 fungal defacement rating scale.

ASTM Rating	Coupon Defacement (%)
10	0
9	1 -10
8	11 - 20
7	21 - 30
6	31 - 40
5	41 - 50
4	51 - 60
3	61 - 70
2	71 - 80
1	81 - 90
0	91 - 100

2.3 Determination of coating resistance to fungal defacement by accelerated 4-week agar plate assay (ASTM D5590)

ASTM 5590 was used to further evaluate coating resistance to fungal defacement. Both sides of round glass fiber filter paper coupons (grade 391, 4 cm) were painted with two coats of each test coating listed in Table 1 using a fine bristle paint brush. Three replicated coupons were coated with each coating and uncoated coupons served as controls. Coupons were allowed to dry 24 hours between coats and 1 week before use. Additionally, the coupons were weighed before and after being painted to ensure consistent coverage. Coupons within one coating subsets that varied greater than ± 1.0 mg were deemed as unevenly coated and discarded. Fungal spore stocks of *A. pullulans*, *A. niger* and *P. citrinum* were prepared according to the ASTM D5590 test method. Spores of *A. niger* and *P. citrinum* were combined and a hemocytometer was used to calculate the number of spores in each of the two spore stocks. The spore stocks were diluted with sterile nutrient salts to a final concentration of 1.0×10^6 spores mL⁻¹. Coupons were placed in the center of 100 x 15 mm, UV-A transmissible, petri plates containing approximately 30 mL of PDA and overlaid with 500 μ mL of each spore stock, either *A. pullulans* or the mixture of *A. niger* and *P. citrinum*. Petri dishes were wrapped with surgical tape to allow air infiltration but to restrict spore release from the plates. Uncoated uninoculated plates served as negative controls and uncoated spore inoculated plates served as positive controls for the test method. All plates were incubated in a Cincinnati Sub-Zero Z-32 Plus (Weiss Technik, Cincinnati, OH) environmental test chamber (Figure 3).

Figure 3. PDA agar plates containing coated and uncoated coupons overlaid with *A. pullulans* or a mixture of *A. niger* and *P. citrinum* prior to incubation in an environmental chamber; (a) UV-A irradiated (top half of chamber), (b) incubated in the dark (bottom half of chamber), and (c) Sub-Zero environmental chamber.



The environmental chamber was separated in two halves where the top half received UV-A at 1.0 mW/cm^2 for 6 hours day⁻¹ and the bottom half remain dark. A 20W, BLB lamp, with a peak wavelength of 365 nm was used for this test method. Light intensity was monitored with an Analytik Jena UVX radiometer with a UVX-36 probe. A constant 28 °C and 86% relative humidity was maintained through the duration of the test. The position of the plates was rotated within the upper half of environmental chamber receiving UV-A irradiation biweekly to ensure an even light distribution on the plates. The susceptibility of the coated surfaces to fungal growth were evaluated every 7 days over a 4-week period. Plates were photographed with a digital camera and ImageJ was used as previously described to calculate the percent of specimen defacement and to measure zones of inhibition if present. Each of the three coating replicates were averaged and the percentages obtained were used to rate disfigurement according to the ASTM scale of 0 to 4 where 0 represents no fungal growth and 4 represents complete coverage (Table 3). Tested coatings were compared, then ranked by their ability to resist fungal contamination.

Table 3. ASTM D5590 fungal defacement rating scale.

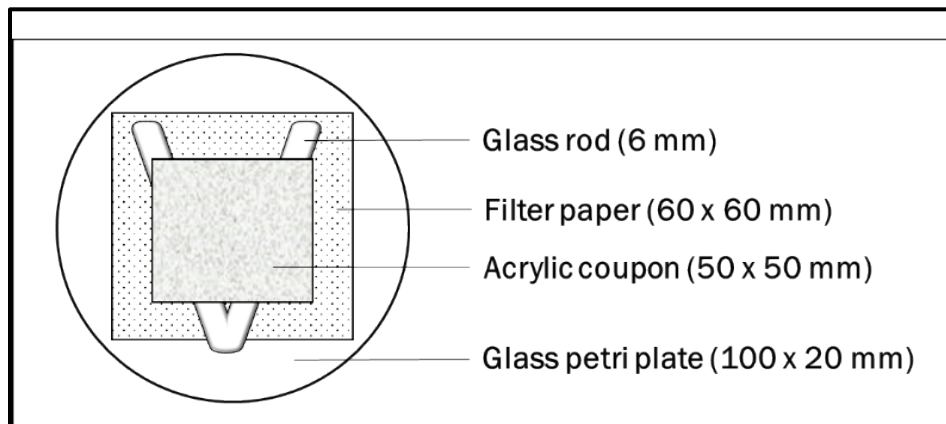
Observed Growth	Specimen Defacement (%)	ASTM Rating
None	0	0
Trace	1 - 9	1
Light	10 - 30	2
Moderate	31 - 60	3
Heavy	61 - 100	4

2.4 Assessment of photocatalytic antifungal activity of Ecoreflex and Ecosil-ME (ISO-13125)

In addition to resisting fungal colonization, each of the photocatalytic coatings were tested for antifungal activity as outlined in ISO-13125. Both photocatalytic coatings were evaluated for their abilities to limit or prevent germination of *A. niger* and *P. citrinum* spores. Coupons used for this assessment measured 50 x 50 mm wide and 3 mm high and were fabricated out of poly(methyl methacrylate) (PMMA). To promote coating adhesion to the acrylic surface, one side of the coupon surface was lightly roughened with 200 grit sandpaper. Before coating, the acrylic coupons were sterilized with 90% ethanol and allowed to air dry before being coated. Aseptically as possible, coupons were coated three times with Ecosil-ME or Ecoreflex on the roughened side of the PMMA with a fine bristle paint brush. Coupons were allowed to dry 24 hours between coats and 1 week before use at room temperature. Roughened, uncoated, acrylic coupons served as controls and each photocatalytic coating was simultaneously tested in triplicate.

Aspergillus niger and *P. citrinum* were grown and spores were harvested as described in ISO 13125. Spores obtained from each species were combined and the total spore concentration was determined microscopically using a hemocytometer. The resulting spore stock was diluted to a final concentration of 1.4×10^5 spores mL^{-1} . One hundred μL of the spore stock was spotted on the surface of each test coupon resulting in approximately 1.4×10^4 spores on each coupon surface. The test specimens were placed in a UV-A transmissible glass test vessels (100 x 20 mm) containing approximately 3 mL diH_2O dispensed onto filter paper to prevent the inoculum from drying out during incubation (Figure 4).

Figure 4. Diagram of test vessel used to evaluate the photocatalytic antifungal activity of Ecoreflex and Ecosil-ME.



All components of the test vessels were sterilized by autoclaving at 120 °C for 20 minutes before use. Spores from one set of uncoated PMMA coupons were immediately recovered, which served as the baseline for spore extraction efficiency from the coupon surface and spore stock viability. The remaining test vessels were either incubated in the dark at 25 °C for 17 hours or irradiated with UV-A at 1.0 mW/cm² for 17 hours at 25 °C. A 20W, BLB lamp, with a peak wavelength of 365 nm, was used for this test method. Light intensity was monitored with an Analytik Jena UVX radiometer with a UVX-36 probe. After incubation, the spores were recovered from the test coupons as described in ISO-13125 and viability was assessed by serially diluting the recovery solution and pour plating with PDA in triplicate. Colonies were counted and the percent of viable spores recovered was calculated. Antifungal activity of the photocatalytic coating was estimated as a ratio of surviving spores relative to controls of the non-coated surfaces.

2.5 Determination of photocatalytic activity of Eco-reflex and Ecosil-ME by degradation of methylene blue in aqueous solution (ISO-10678:2010)

ISO-10678:2010 was used to further test the photocatalytic activity of Eco-reflex and Ecosil-ME. Acrylic coupons made of PMMA were prepared and coated with Eco-reflex or Ecosil-ME as described previously. Uncoated coupons served as controls for the evaluation. All coupons were preconditioned by exposing them with UV-A for 48 hours at 1.5 mW/cm². A solution of 20 mM methylene blue (pH 5.5) was conditioned with UV-A for 24 hours at 1.5 mW/cm² then allowed to sit in the dark for 12 hours before use. Loss of absorbance at 665 nm of the methylene blue solution was monitored over this period and served as measurement of its stability. Coupons were placed into UV-A transmittable, glass test vessels and 30 mL of the stock methylene blue solution was poured over the test specimens to completely cover them in approximately 1 cm of liquid.

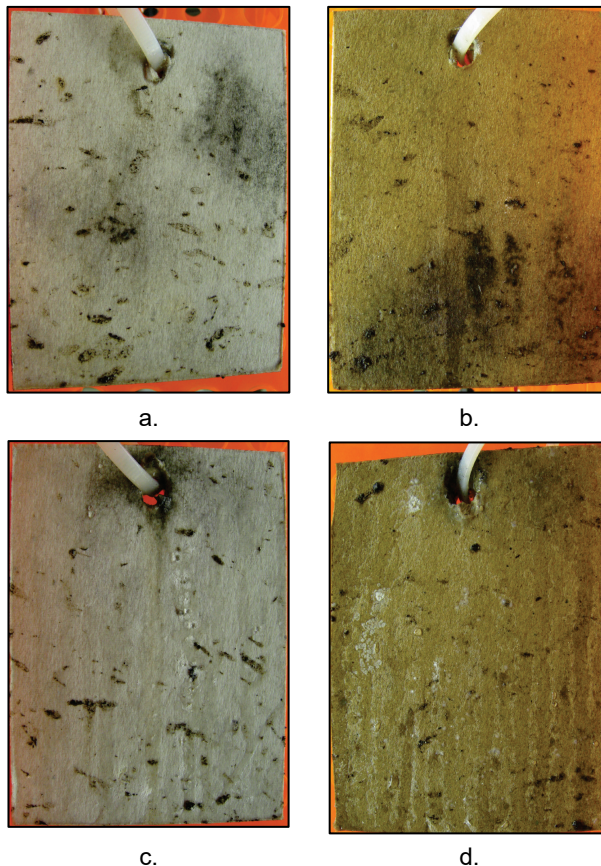
The test vessels were either incubated in the dark at 25 °C or irradiated with UV-A at 1.5 mW/cm² at 25 °C. A 20W, BLB lamp, with a peak wavelength of 365 nm, was used for this test method. Light intensity was monitored with an Analytik Jena UVX radiometer with a UVX-36 probe. Each of the coatings were evaluated over a 3-hour period and degradation of methylene blue was monitored by taking 2 mL samples every 20 minutes and reading the absorbance at 665 nm. All reaction vessels were briefly mixed before and after taking the absorbance readings and samples were poured back into the vessel to keep the reaction volumes consistent throughout the experiment.

3 Results/Discussion

3.1 Evaluation of coating resistance to mold colonization in an environmental chamber (ASTM D3273)

Proper conditioning of each environmental chamber was assessed by exposing both PDA plates and uncoated gypsum coupons to the atmosphere within the chambers. After a 1-hour exposure period, all PDA plates were completely covered with mold growth (data not shown). Furthermore, after 4 weeks of exposure, the gypsum coupons in both environmental chambers were found to have moderate growth equivalent to an ASTM rating ranging from 5 to 6 disfigurement (Figure 5). These results indicated both chambers contained viable fungal spores and were properly conditioned and ready to be used to evaluate the coatings for their ability to inhibit mold proliferation.

Figure 5. Sample images of an uncoated gypsum coupon after 4 weeks exposure in a spore inoculated environmental chambers; (a) front of gypsum coupon in UV-A environmental chamber, (b) back of gypsum coupon in UV-A environmental chamber, (c) front of gypsum coupon in control environmental chamber, and (d) back of gypsum coupon in control environmental chamber.

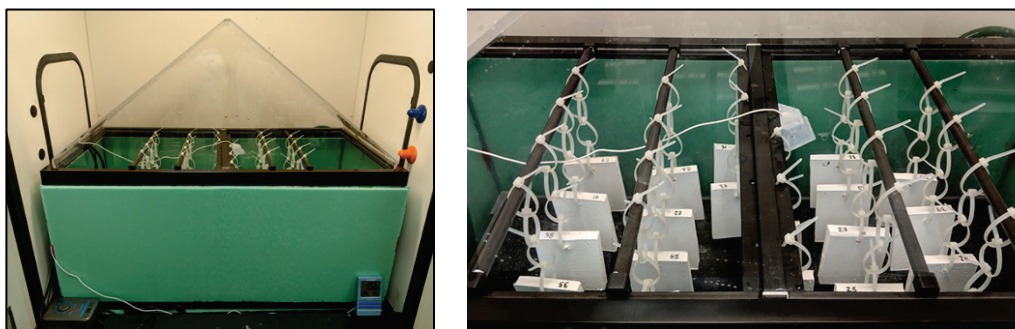


Gypsum was the first substrate to be evaluated with each of the coatings. Figure 6 shows the control chamber (no UV-A exposure) with the gypsum coupons after placing them in the chamber (0-week incubation). Fungal defacement was monitored weekly for 6 weeks and the percent defacement and the associated ASTM rating were calculated (Figure 7). The percent of fungal coverage on the coupons ranged from roughly 6% on the Super-Paint coated coupons incubated under UV-A to nearly 62% covered on the uncoated coupons incubated in the dark.

As expected, the uncoated gypsum coupons overall exhibited the greatest degree of defacement with ASTM ratings ranging from 3.5 ± 0.8 with coupons incubated in the dark and 3.8 ± 1.2 with coupons exposed to UV-A for 3 hours day⁻¹. SuperPaint and Sporicidin were among the top performing coatings in this test under each incubation condition. SuperPaint incubated in the dark had an ASTM rating of 8.7 ± 0.5 and a rating of 8.8 ± 0.4 when incubated with UV-A light. Sporicidin incubated in the dark had a rating of 8.8 ± 0.4 and a rating of 8.5 ± 0.8 when incubated with UV-A light. After-shock was the third best overall performing coating with ratings of 8.2 ± 0.8 when incubated in the dark and 8.5 ± 0.6 when incubated with UV-A light.

However, no differences could be determined between these three coatings and the other coatings tested except Ecoreflex incubated under UV-A, which had a rating of 7.0 ± 0.0 and Zinsser incubated either incubation condition. Zinsser incubated in the dark had a rating of 5.3 ± 1.2 and a rating of 4.5 ± 1.9 when incubated with UV-A light, which clearly demonstrated that Zinsser, a very commonly used primer for gypsum, was the most susceptible to fungal growth under these test conditions.

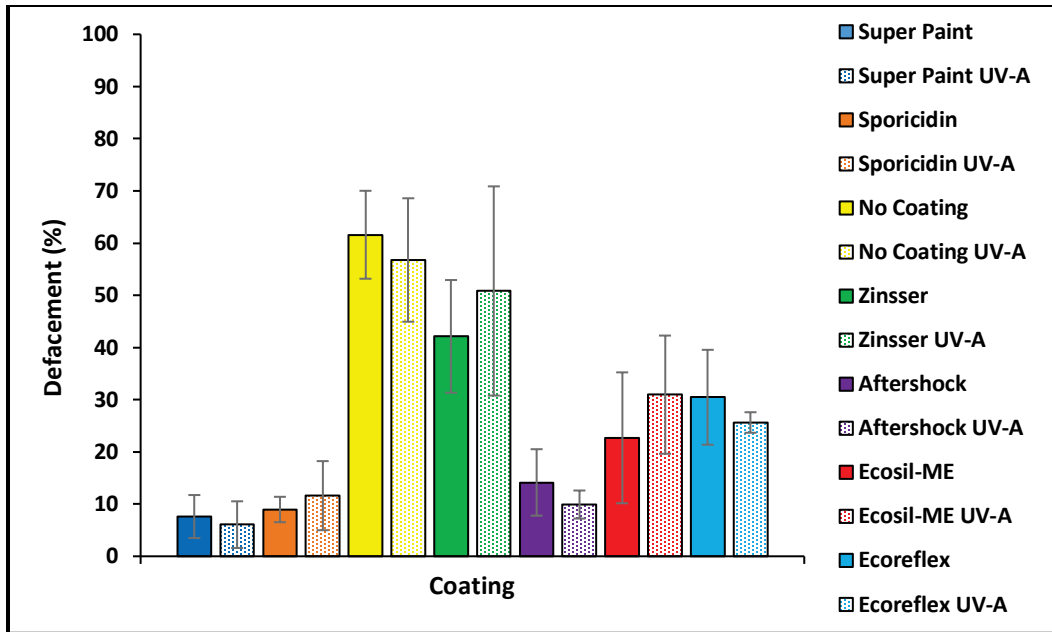
Figure 6. Control environmental chamber (no UV-A) with gypsum coupons. All coatings and uncoated controls were tested simultaneously; (a) view from the side, and (b) view from the top of the environmental chamber. Images show coupons at start of the experiment.



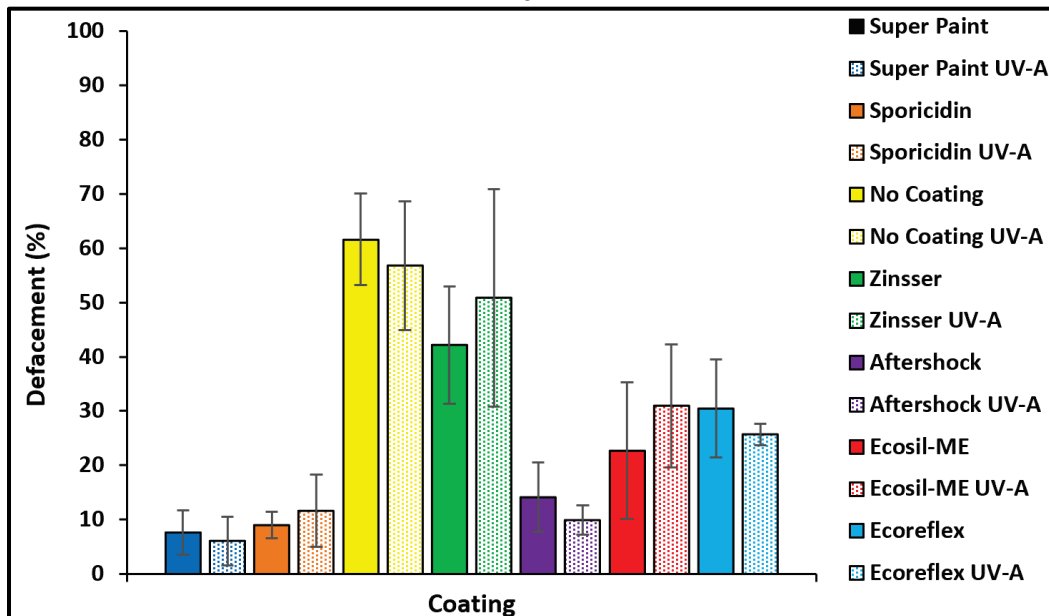
a.

b.

Figure 7. Fungal growth on gypsum coupons after 6 weeks incubation in the environmental chambers; (a) percent defacement as determined by ImageJ, and (b) ASTM ratings based on percent defacement. Each bar represents the average mean percent fungal coverage (n=6). The error bars represent the standard deviation.



a.

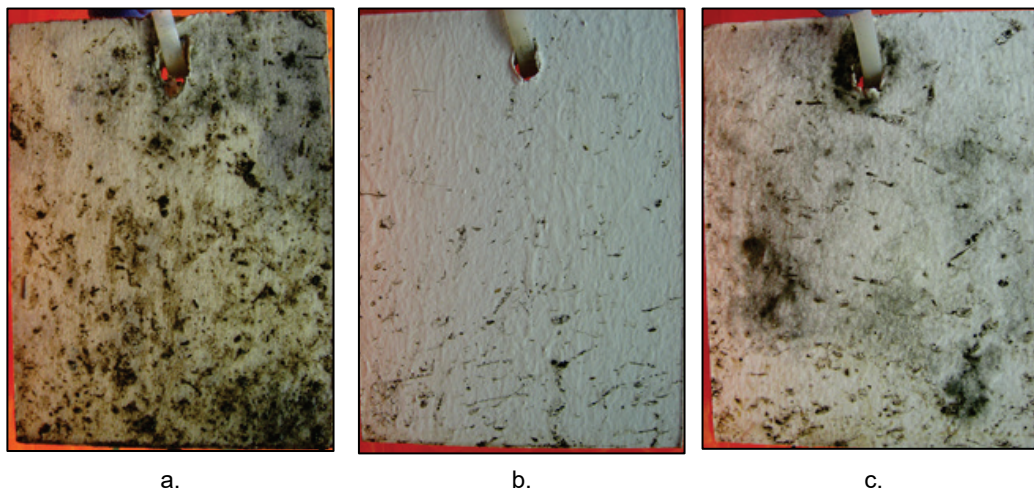


b.

Note that no significant differences in fungal defacement were observed between any of individual coatings tested whether the coupons were incubated in the dark or in the presence of UV-A. This indicated that UV-A exposure had little or no effect on fungal proliferation on the coated surfaces including the photocatalytic infused coatings.

Figure 8 shows examples of low and high fungal defacement on coupons exposed to UV-A light. Although coating the gypsum coupons with antimicrobials did reduce defacement, SuperPaint (latex control) performed as well and even better in the evaluation using ASTM D3273, which suggests that simply encapsulating the coupons, e.g., limiting moisture and nutrients, may provide an adequate antifungal effect on gypsum.

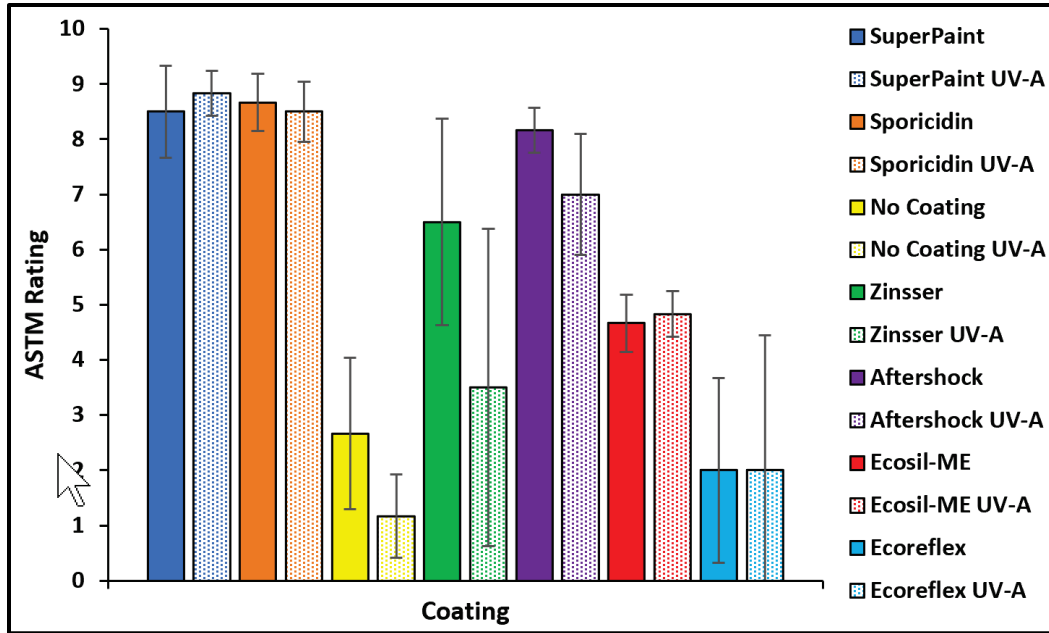
Figure 8. Fungal defacement on gypsum after exposure to UV-A 3 hours day⁻¹ for 6 weeks; (a) uncoated, (b) SuperPaint, and (c) Zinsser.



Pine was the second substrate to be evaluated with each of the coatings under ASTM D3273 test conditions. Results observed were similar to those of the coated gypsum coupons in that the uncoated pine coupons exhibited the highest degree of fungal defacement having ASTM ratings of 2.7 ± 1.4 and 1.2 ± 0.8 for coupons incubated in the dark and under UV-A 3 hours day⁻¹, respectively (Figure 9).

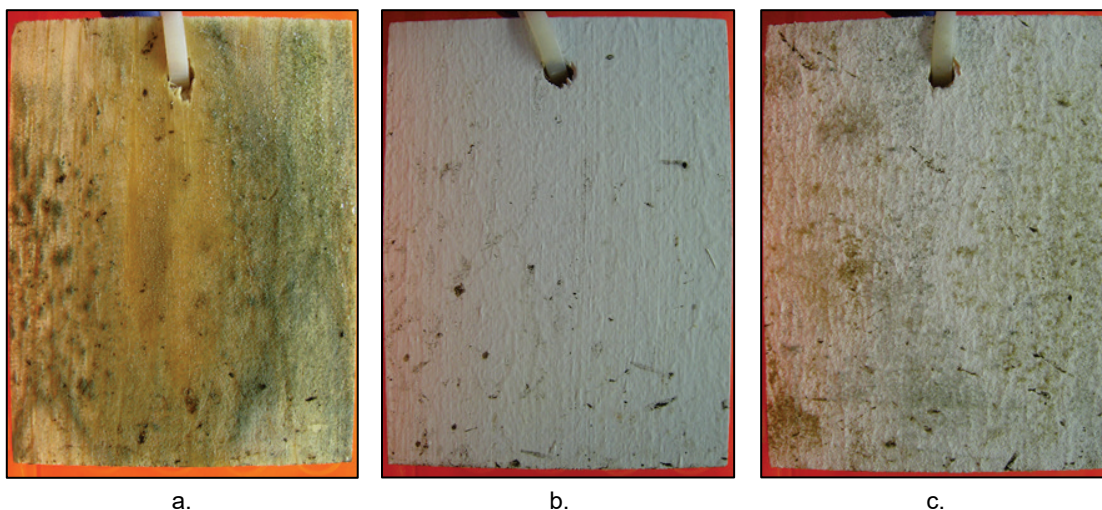
SuperPaint and Sporicidin were again among the top performing coatings followed by Aftershock. SuperPaint incubated in the dark had an ASTM rating of 8.5 ± 0.8 and a rating of 8.8 ± 0.4 when incubated with UV-A light. Sporicidin incubated in the dark had a rating of 8.7 ± 0.5 and a rating of 8.5 ± 0.6 when incubated with UV-A light. Aftershock had ratings when incubated in the dark and with UV-A exposure of 8.2 ± 0.4 and 7.0 ± 1.1 , respectively. Neither of the photocatalytic infused coating performed as well as these three coatings. Ecosil-ME had rating for dark incubation of 4.7 ± 0.5 and UV-A exposed of 4.8 ± 0.4 . Ecoreflex was the least resistant to fungal colonization on the wood substrate having ratings of 2.0 ± 1.7 and 2.0 ± 2.5 (dark and UV-A exposed, respectively).

Figure 9. ASTM rating of pine coupon defacement as determined by ImageJ after 4 weeks incubation in the environmental chambers. Each bar represents the average mean percent fungal coverage (n=6). The error bars represent the standard deviation.



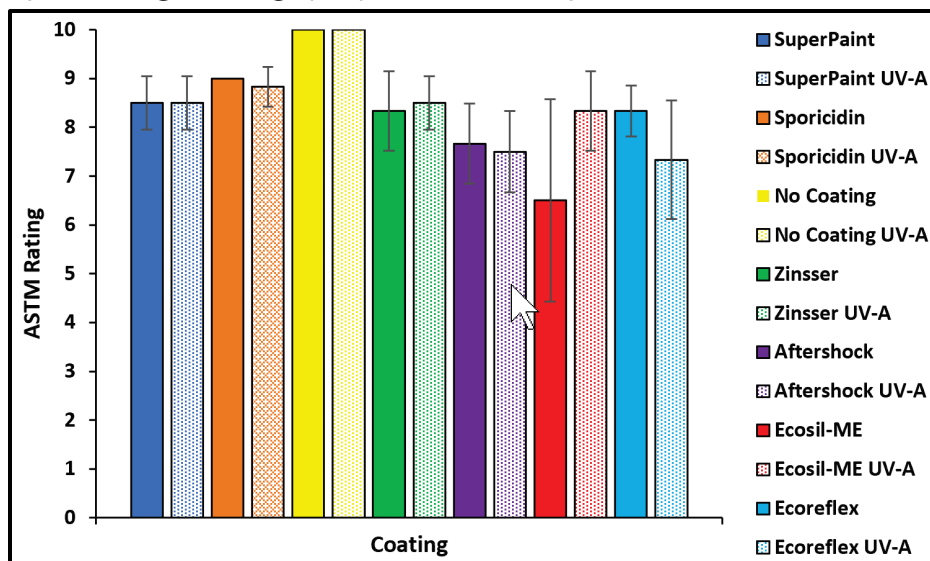
As observed with the gypsum coupons, no statistical differences in fungal defacement could be made between all the coatings tested whether the coupons were incubated in the dark or in the presence of UV-A. These data indicated irradiation had no measurable effect on fungal resistance. Figure 10 represents examples of low and high defacement on pine coupons all of which were UV-A exposed.

Figure 10. Fungal defacement on pine after exposure to UV-A 3 hours day⁻¹ for 5 weeks; (a) uncoated, (b) SuperPaint, and (c) Ecoreflex.



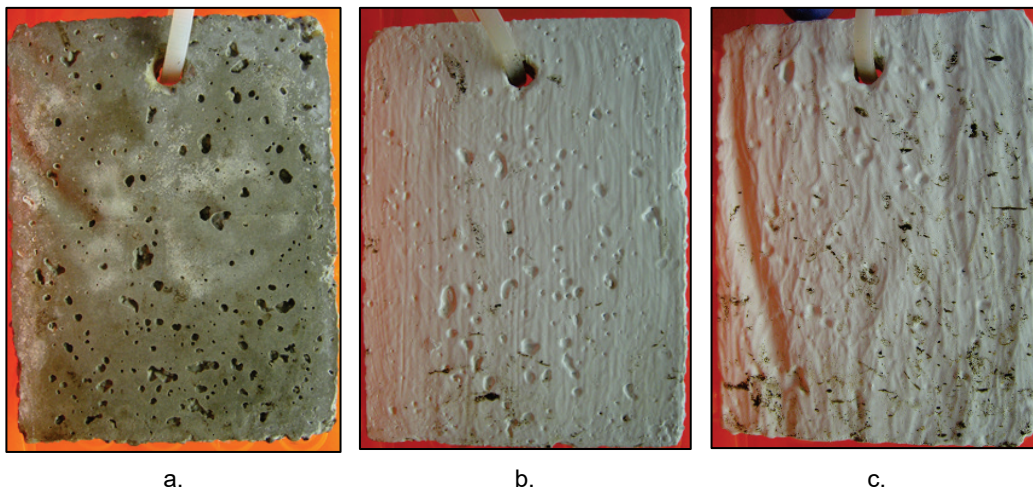
Concrete was the third substrate to be evaluated using the ASTM D3273 test method. Fungal defacement was far less pronounced on the concrete coupons compared to gypsum and wood substrates (Figure 11). Furthermore, the uncoated coupons were found to be the most resistant to fungal colonization having ASTM ratings of 10.0 ± 0.0 for both incubation conditions. The ASTM ratings showed only light defacement for all the coating tested ranging from 9.0 (Sporicidin dark incubation) to 6.5 (Ecosil-ME dark incubation). No statistical variation could be distinguished between any of the coatings tested or UV-A exposure of any one individual coating.

Figure 11. ASTM rating of concrete coupon defacement as determined by ImageJ after 4 weeks incubation in the environmental chambers. Each bar represents the average mean percent fungal coverage ($n=6$). The error bars represent the standard deviation.



The increase in resistance to fungal contamination on the uncoated coupons was likely due to surface pH. Concrete is a highly alkaline composite; the pH of newly formed concrete typically ranges from 11 to 13 (Kakade 2014). Testing of untreated concrete panels with pH test strips revealed a pH of roughly 11 on the surfaces. While fungi can proliferate at acidic to moderately basic pH, very few can tolerate pH greater than 9 (Wheeler et al. 1991). Although surface pH was not monitored on the experimental coupons, it was believed that the coatings used formed a protective barrier from the alkaline surface, which allowed for light defacement on the surfaces. While exposure to the high pH on the uncoated panels prevented colonization. Figure 12 shows examples of typical defacement on concrete coupons, which were all UV-A exposed. Note that the white material on the uncoated coupon was determined to be crystalline in nature by microscopic analysis; it was thus presumed to be mineral effervesces and was therefore excluded from ImageJ analysis.

Figure 12. Fungal defacement on gypsum after exposure to UV-A 3 hours day⁻¹ for 5 weeks; (a) uncoated, (b) SuperPaint, and (c) Ecosil-ME.



Differentiation between coatings on a concrete substrate using standard conditions outlined in the ASTM D3273 test method were found to be insufficient and no coating was observed to outperform another in the ASTM-recommended 4-week test period. Additionally, as with gypsum and wood substrates, no variation between coupons that received UV-A irradiation or coupons incubated in the dark could be detected. This observation again suggested that UV-A exposure seemingly had no measurable effect on fungal colonization on the surface of concrete coupons whether the coating contained a photocatalyst or not.

Of the substrates tested with ASTM D3273, the standard latex SuperPaint performed as well or better at resisting fungal defacement than any of the antimicrobial coatings tested. Sporicidin was overall the best antimicrobial-infused coating at preventing fungal colonization and performed similar to SuperPaint. On a gypsum substrate, all other coatings were found to be relatively equal at resisting defacement using the test method over except Zinsser, which had ASTM ratings similar to uncoated coupons. The Ecosil-ME and Ecoreflex performed best on the gypsum substrate; however, no differentiation could be made between coupons exposed to UV-A or incubated in the dark. On pine, both photocatalytic coatings and Zinsser were found to perform poorly compared to SuperPaint, Sporicidin, and Aftershock and again no differentiation between coupons incubated in the dark or UV-A irradiated could be made.

All coatings performed relatively the same on concrete, which was believed to be due to surface pH. Although the test was run for the ASTM recommended 4-week period, it may be necessary to extend the incubation

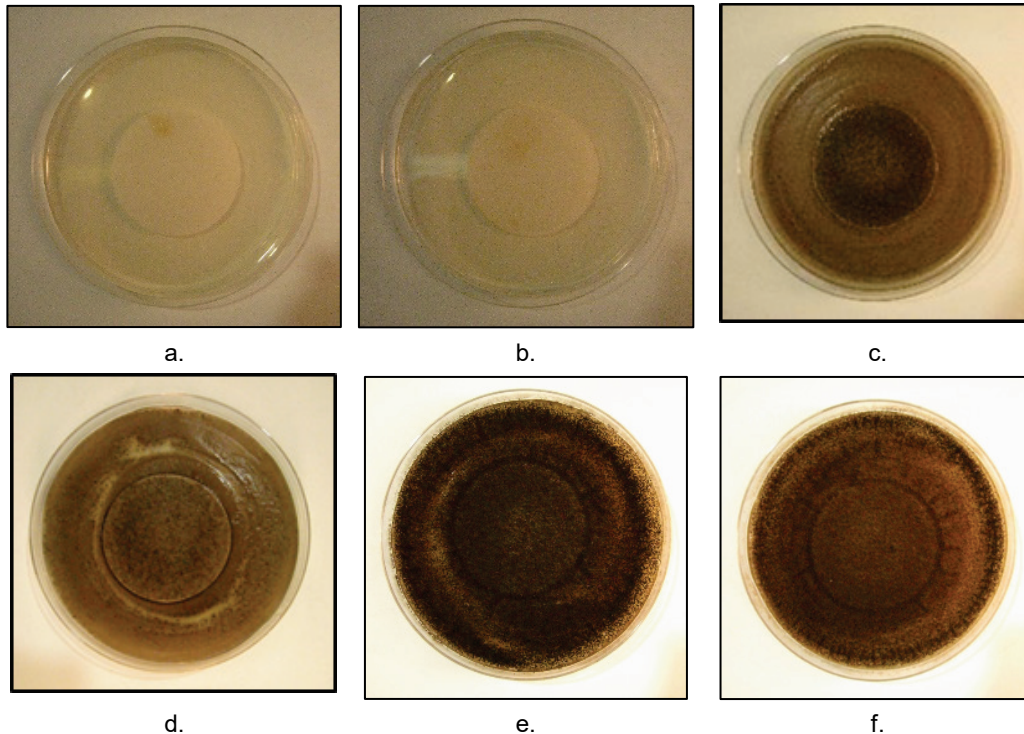
several more weeks to better evaluate the coatings on the substrate. Also, the low organic content of the concrete likely contributed to the relatively slow growth. Overall irradiation with UV-A had no quantifiable effect on the susceptibility of any of the coated surfaces to fungal defacement including the photocatalytic coatings. However, note that the coupons were irradiated for 3 hours day⁻¹ hanging in a vertical position. The 3-hour day⁻¹ UV-A exposure was chosen as a practical time period for indoor application purposes (e.g., irradiation with a BLB lamp). Although the environment chamber was exposed to roughly 1.0 mW/cm² UV-A, which has been demonstrated to drive coating catalysis, the vertical position and the duration of irradiation period may have limited photocatalysis (Auvinen and Wirtanen 2008, Vučetić et al. 2014). Thus, each coating was reevaluated using ASTM 5590 test method where the UV-A exposure was increased in an effort to maximize possible photocatalytic activity.

3.2 Determination of coating resistance to fungal defacement by accelerated 4-week agar plate assay (ASTM 5590)

To determine if UV-A exposure was a limiting factor in photocatalytic coating activity, an accelerated agar plate assay was performed in which the coatings were incubated horizontal to the UV-A source. In addition, the irradiation period was increased to 6 hours day⁻¹. From an indoor application perspective this exposure time was deemed to be the maximum for most practical applications where building occupants would be present.

After the 4-week incubation period, the plates were rated using the ASTM standard; if zones of inhibition were present, they were measured. The plates containing uncoated test coupons, without inoculum (no spores), exhibited no fungal growth. Plates containing uncoated coupons and inoculum, either *A. pullulans* or the mixture of *A. niger* and *P. citrinum* spores, were completely covered with fungi (100%) and showed no zones of inhibition (Figure 13). Additionally, UV-A exposure had no apparent influence on the growth of *A. pullulans* or the mixture of *A. niger* and *P. citrinum*. This established the viability of the spore stocks and indicated that no cross contamination within the environmental chamber occurred over the 4-week incubation period. Furthermore, the uncoated test coupons exhibited no fungal inhibition.

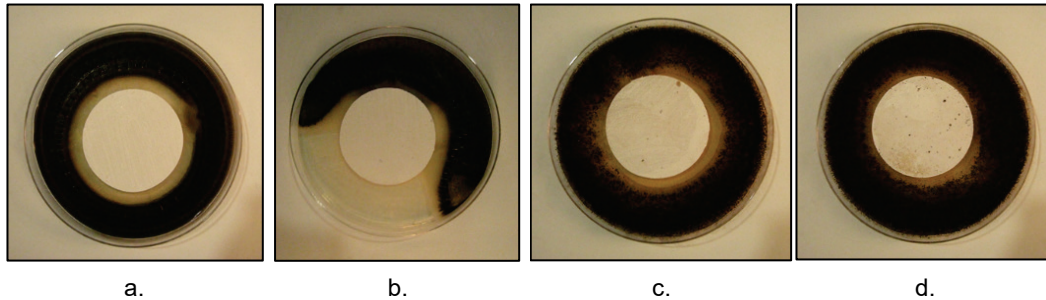
Figure 13. Fungal colonization on uncoated test coupons incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) uninoculated, (b) uninoculated +UV-A, (c) inoculated with *A. pullulans*, (d) inoculated with *A. pullulans* +UV-A, (e) inoculated with *A. niger* and *P. citrinum*, and (f) inoculated *A. niger* and *P. citrinum* +UV-A.



Under ASTM 5590 test conditions, Sporicidin was found to be the best performing coating based on the combination of both ASTM ratings and zones of inhibition (Figure 14). When the coating was overlaid with *A. pullulans*, no growth (0%) was observed on any of the coupons tested and zones of inhibition ranged from 5 mm to greater than 10 mm. Interestingly, all replicates irradiated with UV-A developed a zone of inhibition that extended to the edge of the test plate approximately half the circumference around the test vessel (Figure 14b). This pattern of inhibition was not observed for any other coating or test condition. The exact cause of this phenomenon could not be explained and warrants further study as it was unclear if the combination of Sporicidin and UV-A had an effect on the growth of *A. pullulans*. The mixed spore overlays were found to be slightly less susceptible to inhibition but were still determined to be less than 1% covered, giving them an ASTM rating of 0. The mixed spore zones of inhibition ranged from 3 to 6 mm and 2 to 4 mm in the non-irradiated and UV-A exposed plates, respectively. Additionally, the zones of incubation were found to be less pronounced in the mixed spore overlaid test vessels. Collectively, these observations suggested that Sporicidin was slightly less effective on the fungal mixture and that UV-A irradiation may have

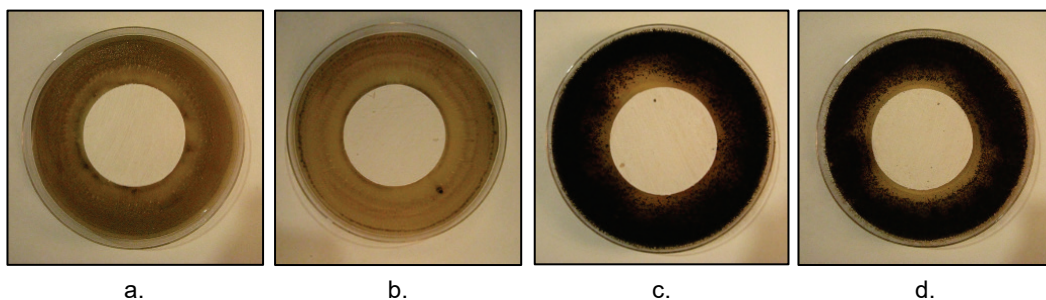
affected the coatings antimicrobial efficiency. Again, the phenomenon illustrated in Figure 14b needs further study (which was beyond the scope of this work) to determine the effect of UV-A under these test conditions.

Figure 14. Fungal colonization on test coupons coated with Sporicidin and incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) inoculated with *A. pullulans*, (b) inoculated with *A. pullulans* +UV-A, (c) inoculated with *A. niger* and *P. citrinum*, and (d) inoculated *A. niger* and *P. citrinum* +UV-A.



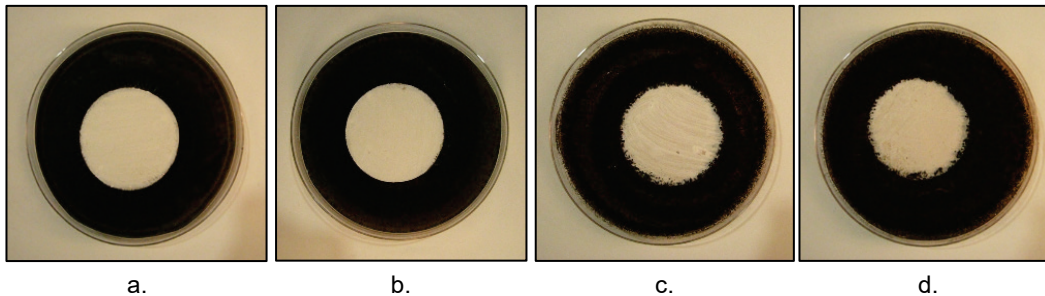
Similar to Sporicidin, SuperPaint was also determined to resist fungal growth almost completely under the ASTM test conditions (Figure 15). When coupons coated with SuperPaint were incubated under both dark and UV-A irradiated conditions, the percent *A. pullulans* and the mixture of *A. niger* and *P. citrinum* coverage was 0% and <1% respectively, resulting in ASTM ratings of 0 for each. Zones of inhibition were not observed on coupons overlaid with *A. pullulans* spores incubated either in the dark or under UV-A light. However, significant zones of inhibition were observed on coupons overlaid with the spore mixture under both incubation conditions, which ranged from approximately 2 to 5 mm. This observation suggested the coating elicited a greater antifungal effect against *A. niger* and *P. citrinum*. Irradiation with UV-A had no apparent effect on the size of the inhibitory zone formed around the test coupons of the spore mix but did seemingly limit spore production with *A. pullulans*.

Figure 15. Fungal colonization on test coupons coated with SuperPaint and incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) inoculated with *A. pullulans*, (b) inoculated with *A. pullulans* +UV-A, (c) inoculated with *A. niger* and *P. citrinum*, and (d) inoculated *A. niger* and *P. citrinum* +UV-A.



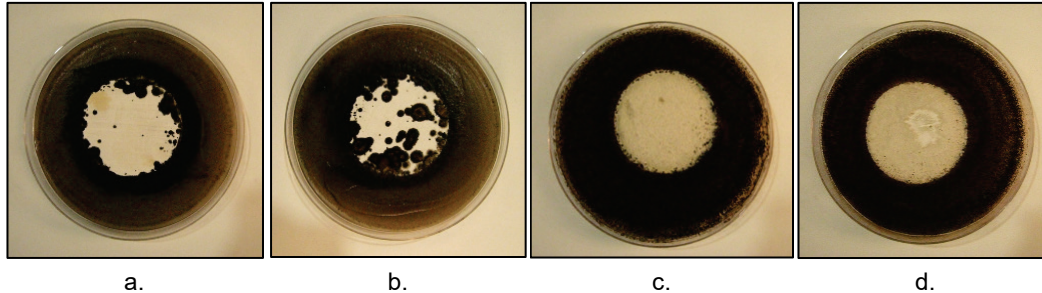
Aftershock coated coupons overlaid with *A. pullulans* were found to have very slight coverage (<1%) on the very outer edges of the coupons when incubated in either the dark or when irradiated with UV-A, resulting in an ASTM ranking of 0 for both conditions (Figure 16). Coated coupons overlaid with the spore mixture were found to have light coverage (17-18%) around the outer edge of the coupons when incubated under either lighting condition resulting in ASTM rankings of 1 for each. No zones of inhibition were observed under any of the conditions tested with Aftershock coated coupons and UV-A exposure had no apparent effect on the coating's antimicrobial activity. These data suggested that the coating was somewhat more active against *A. pullulans* than the mixed inoculum.

Figure 16. Fungal colonization on test coupons coated with Aftershock and incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) inoculated with *A. pullulans*, (b) inoculated with *A. pullulans*+UV-A, (c) inoculated with *A. niger* and *P. citrinum*, and (d) inoculated *A. niger* and *P. citrinum*+UV-A.



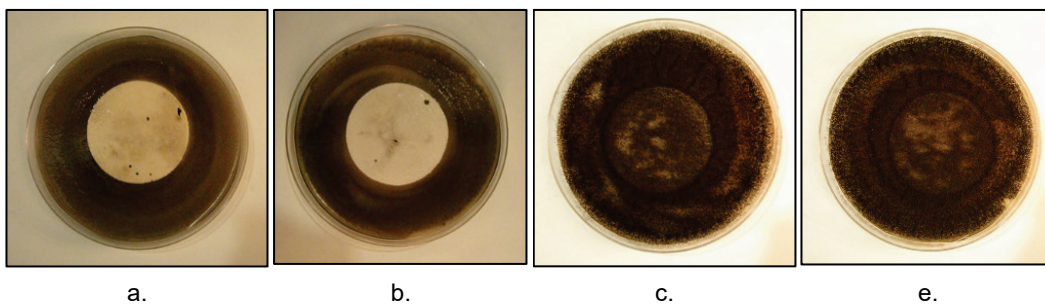
Zinsser coated coupons overlaid with *A. pullulans* were found to have light coverage (24%) when incubated in the dark and moderate coverage (58%) when irradiated with UV-A resulting in an ASTM rankings of 2 and 3 respectively (Figure 17). Zinsser coated coupons overlaid with the spore mixture of *A. niger* and *P. citrinum* were found to have light coverage (16%) when incubated in the dark and trace coverage (9%) when irradiated with UV-A resulting in an ASTM rankings of 2 and 1, respectively. No zones of inhibition were observed under any condition tested with Zinsser coated coupons. These data suggested that the coating was more active against the mixed inoculum than *A. pullulans*. Overall, UV-A exposure for 6 hours day⁻¹ may have exhibited a negative effect on coupons overlaid with *A. pullulans* and a marginally positive effect on plates overlaid with the spore mixture.

Figure 17. Fungal colonization on test coupons coated with Zinsser and incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) inoculated with *A. pullulans*, (b) inoculated with *A. pullulans*+UV-A, (c) inoculated with *A. niger* and *P. citrinum*, and (d) inoculated *A. niger* and *P. citrinum*+UV-A.



Heavy to moderate coupon coverage was observed on the Ecosil-ME coated coupons inoculated with *A. pullulans* when incubated in the dark and with UV-A exposure, 70% and 60% respectively (Figure 18). The slight decrease in coupon coverage on the UV-A exposed test vessels was possibly due to photocatalytic activity of the coating. However, very heavy growth was observed when the Ecosil-ME coated coupons were inoculated with the mixed spore inoculum under both dark and UV-A exposed incubation conditions resulting in 100% coverage on both. No differences between mixed spore cultures incubated in the dark or exposed to UV-A were observed. Additionally, no zones of inhibition were present under any test condition. These data suggested that Ecosil-ME may have had weak photocatalytic activity against *A. pullulans*, but no activity was observed with the mixture of *A. niger* and *P. citrinum*.

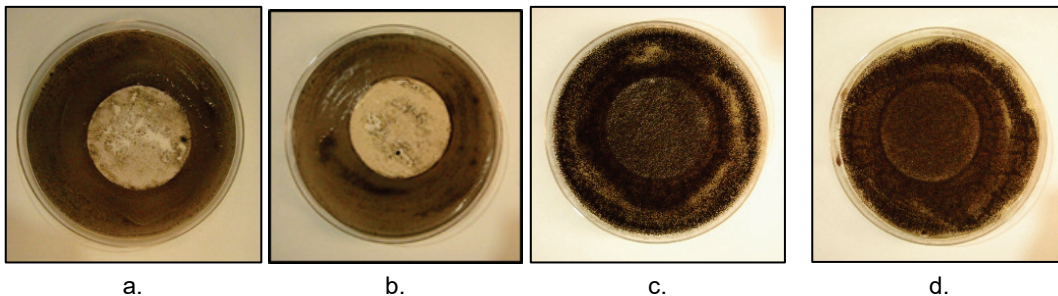
Figure 18. Fungal colonization on test coupons coated with Ecosil-ME and incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) inoculated with *A. pullulans*, (b) inoculated with *A. pullulans*+UV-A, (c) inoculated with *A. niger* and *P. citrinum*, and (d) inoculated *A. niger* and *P. citrinum*+UV-A.



As with Ecosil-ME, Ecoreflex was seemingly able to reduce fungal coverage on *A. pullulans* overlaid coupons from approximately 93% coverage to 64% coverage on the UV-A irradiated plates, which indicated possible photocatalytic activity of the coating (Figure 19). Similar to Ecosil-ME coated

coupons, very heavy growth was observed on Ecoreflex coated coupons overlaid with the spore mixture. Plates incubated in the dark and exposed to UV-A showed 100% fungal coverage for both incubation conditions. Additionally, no zones of inhibition were observed under any test condition incubated with the single fungal species or the spore mix. These observations indicated that Ecoreflex may have had slight photocatalytic activity against *A. pullulans* but no effect on the mixed spore culture under the ASTM test conditions.

Figure 19. Fungal colonization on test coupons coated with Ecoreflex and incubated in the dark or exposure to UV-A 6 hours day⁻¹ for 4 weeks; (a) inoculated with *A. pullulans*, (b) inoculated with *A. pullulans* +UV-A, (c) inoculated with *A. niger* and *P. citrinum*, and (d) inoculated *A. niger* and *P. citrinum* +UV-A.



As observed with ASTM D3273, Sporicidin and SuperPaint were very effective at preventing fungal growth followed by Aftershock overall. Table 4 lists the coatings in descending order of performance based on the combination of ASTM ratings and zones of fungal inhibition. SuperPaint and Sporicidin were the only coatings that exhibited zones of inhibition using the test method. Based on these zones, Sporicidin was found to be very effective against all three fungal species tested. SuperPaint was less effective against *A. pullulans* but still performed very well at resisting fungal defacement. Aftershock also performed well against all three species with only trace fungal coverage on coupons inoculated with the mixed spore culture; however, no inhibition zones were observed. Both of the catalytic TiO₂ infused coatings, Ecosil-ME and Ecoreflex, were found to perform poorly against the fungal growth for all the species tested. However, both did seem to show slight photocatalytic activity against *A. pullulans* but were still rated at moderate to heavy coverage. Even with the increased UV-A exposure, the photocatalytic coatings demonstrated very poor antifungal performance compared to the biocide-infused and standard latex coatings.

Table 4. Coating resistance to fungal defacement as determined by ASTM 5590 after 4 weeks incubation at 28 °C and 85% relative humidity. Values are the means three experimental replicates (n=3).

Coating	<i>A. pullulans</i>				<i>A. niger and P. citrinum</i>			
	Dark		UV-A		Dark		UV-A	
	ASTM	Inhibition	ASTM	Inhibition	ASTM	Inhibition	ASTM	Inhibition
	Rating	(mm)	Rating	(mm)	Rating	(mm)	Rating	(mm)
- Control	0	0	0	0	0	0	0	0
+ Control	4	0	4	0	4	0	4	0
Sporicidin	0	5-10	0	>10	0	3-6	0	2-4
SuperPaint	0	0	0	0	0	2-5	0	2-5
Aftershock	0	0	0	0	2	0	2	0
Zinsser	2	0	3	0	2	0	1	0
Ecosil-ME	4	0	3	0	4	0	4	0
Ecoreflex	4	0	4	0	4	0	4	0

3.3 Assessment of photocatalytic coating antifungal activity (ISO-13125)

The ISO-13125 standard test method was used to better assess the antifungal activity of the photocatalytic coatings. Acrylic coupons were coated with Ecosil-ME or Ecoreflex and spotted with a mixture of *A. niger* and *P. citrinum* spores, then irradiated with UV-A or incubated in the dark for 17 hours (Figure 20). After the incubation period, the spores were recovered from the surfaces of the coupon, pour plated in PDA, fungal colonies were counted, and spore survival was calculated (Figure 21).

Figure 20. Uncoated and photocatalyst coated coupons being irradiated with UV-A at 1.0 mW/cm² for 17 hours; (a) uncoated, (b) Ecosil-ME coated, (c) Ecoreflex coated, and (d) test specimens incubated in the dark under a black plastic bag.

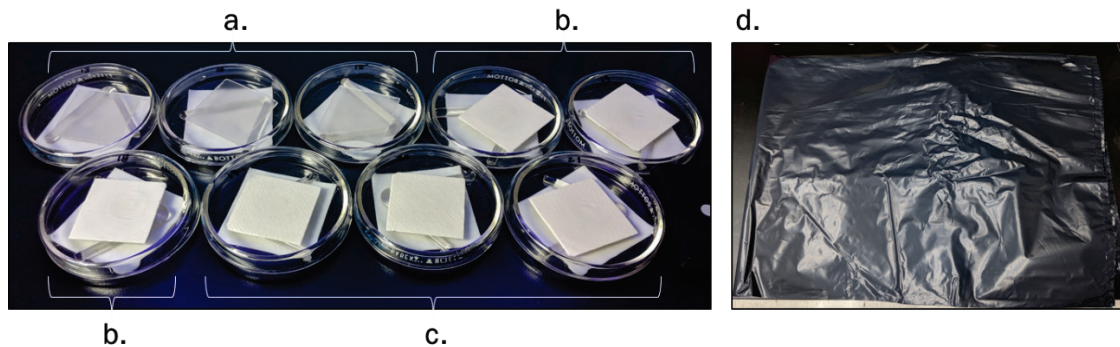
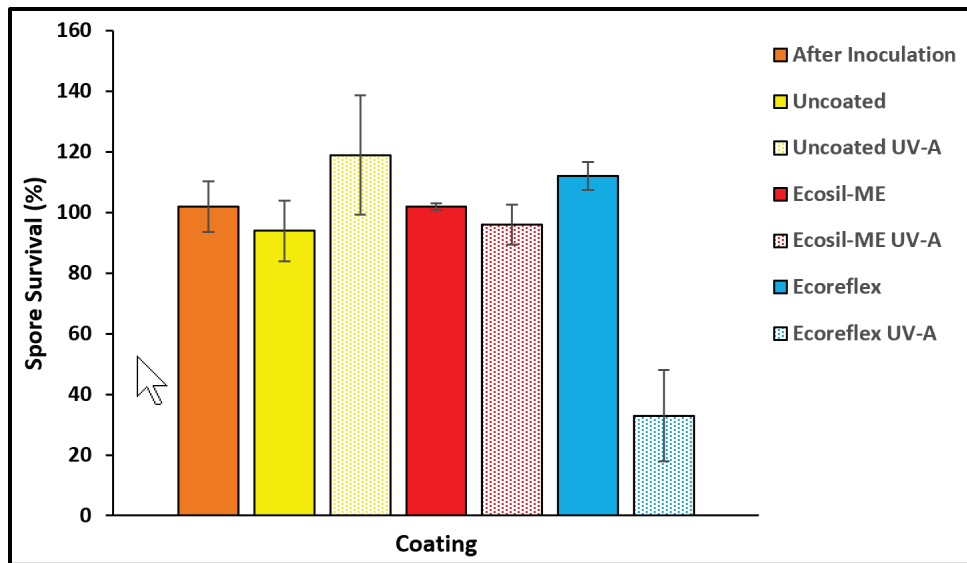


Figure 21. Fungal spore survival on uncoated acrylic coupons and coupons coated with Ecosil-ME and Ecoreflex incubated in the dark or irradiated with UV-A at 1.0 mW/cm² for 17 hours. The error bars represent the standard deviation (n = 3).



Spore survival was assessed immediately after inoculation and was found to be $102 \pm 8\%$ based on the target number of spores spotted on the coupons. This served as the baseline for spore recovery and viability for the experiment and was used to compare each photocatalytic coating. Spore survival on the uncoated coupons incubated in the dark was $94 \pm 10\%$ and coupons incubated under UV-A was $119 \pm 20\%$, which demonstrated efficient spore recovery and viability, and that UV-A exposure alone had no negative effect on spore viability.

No significant differences were found when comparing spore survivability on coupons coated with Ecosil-ME incubated either in the dark or under UV-A. Spore survival when incubated in the dark was $102 \pm 1\%$, and when incubated under UV-A was $96 \pm 7\%$. The percent survival for each test conditions suggested that spores were both effectively recovered from the coated surface and the coating had no apparent antifungal activity under the test conditions used.

Coupons coated with Ecoreflex however did demonstrate antifungal activity by either inhibiting germination or inactivating the fungal spores. Ecoreflex coupons incubated in the dark had spore survival of $112 \pm 5\%$ and when incubated under UV-A had a survival of only $33 \pm 15\%$. Coating coupons with Ecoreflex resulted in nearly a 71% decrease in spore colonies when incubated under UV-A, which clearly demonstrated photocatalytic antifungal activity of the coating.

Although Ecoreflex did demonstrate effective antifungal activity, 17 hours of constant UV-A exposure at 1.0 mW/cm² was required. This exposure period would make it impractical for most interior applications to control fungal proliferation. However, Ecoreflex is marketed for exterior use also where exposure to the sun could make it an effective coating for controlling fungal defacement, which is the focus of future studies.

3.4 Determination of photocatalytic activity of Ecoreflex and Ecosil-ME by degradation of methylene blue in aqueous solution (ISO-10678:2010)

Photocatalytic activity was further evaluated by monitoring the degradation of methylene blue in a reaction vessel with acrylic coupons coated with either Ecoreflex or Ecosil-ME and incubated in the dark or under continual UV-A irradiation at 1.5 mW/cm² (Figures 22 and 23). Before starting the degradation experiments, the stability of the methylene stock solution was assessed by measuring the change in absorbance at 665 nm. No loss was observed over a 60-hour period, which confirmed that the solution was stable (data not shown). Additionally, no loss of absorbance was measured in reaction vessels containing uncoated coupons irrespective of the incubation conditions, which again confirmed the stability of the methylene blue solution under UV-A irradiation.

Figure 22. Loss of absorbance at 665 nm in reaction vessels containing uncoated and Ecoreflex coated coupons incubated in the dark or irradiated with UV-A at 1.5 mW/cm² over a 3-hour incubation period.

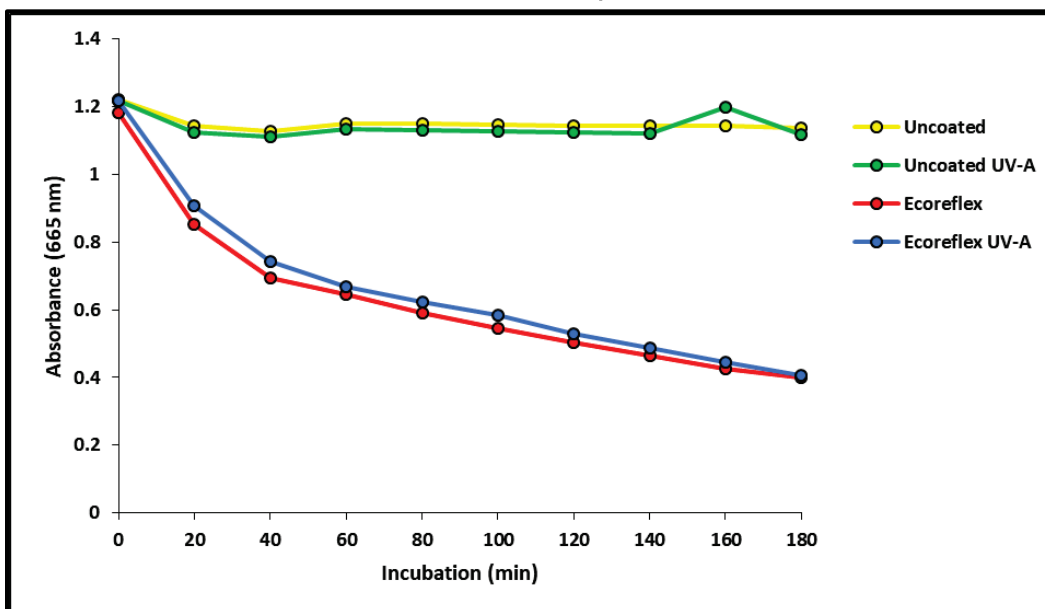
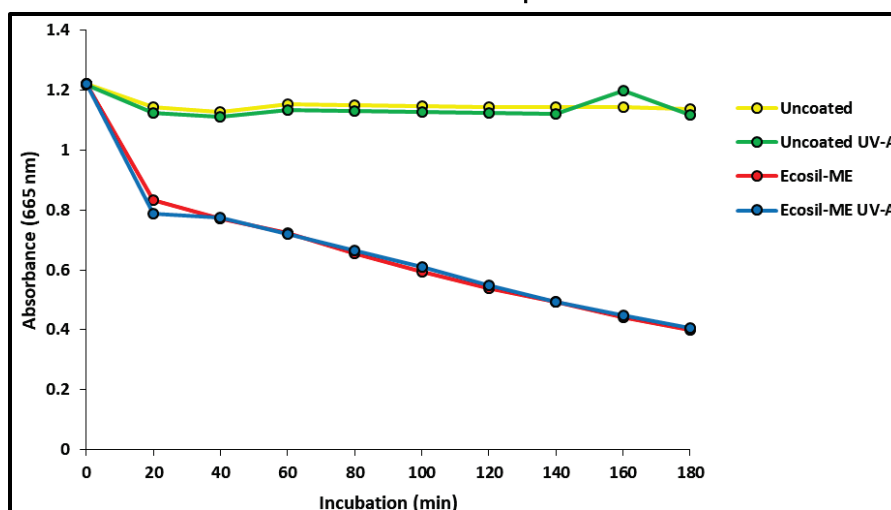


Figure 23. Loss of absorbance at 665 nm in reaction vessels containing uncoated and Ecosil-ME coated coupons incubated in the dark or irradiated with UV-A at 1.5 mW/cm² over a 3-hour incubation period.



Neither Ecosil-ME nor Ecoreflex coated coupons incubated in the presence of UV-A exhibited a loss of absorbance greater than the controls, which were incubated in the dark. When coupons coated with Ecoreflex were incubated in the dark or under UV-A light, a 66% decrease in absorbance was measured over the course of the experiment. When coupons coated with Ecosil-ME were incubated in the dark or under UV-A light, a 67% decrease in absorbance was measured. The uncoated control coupons decreased 7% to 8% over the 3-hour incubation period. This suggested very little or no photocatalytic degradation of methylene blue took place in the presence of either coating under these test conditions.

The loss of absorbance for each coating under both incubation conditions was found to be primarily due to absorption onto the coating surfaces and not due to photocatalytic activity. To better and more accurately assess the catalytic activity of either coating, an alternative test method may be required. Note that, due to a limited number of coated acrylic coupons, no experimental replications were performed during this experiment. Nonetheless, throughout this comparative study, Ecosil-ME and Ecoreflex consistently performed poorly in comparison with the other coatings tested. With the test methods using limited UV-A exposure, little to no differentiation in fungal growth could be determined between UV-A irradiated and non-irradiated cultures. Collectively, this observation suggested photocatalytic activity of Ecoreflex and Ecosil-ME was likely low under the test conditions used; similarly, degradation of methylene blue likely occurred only in a limited capacity if at all with either of the catalytic coatings.

4 Conclusions

This study compared two next-generation photocatalytic coatings against three more traditional antimicrobial-infused coatings for their ability to resist fungal defacement under three accelerated test conditions. With each method used, the photocatalytic coatings were generally found to perform poorly compared to the antimicrobial-infused coatings. Furthermore, the control coating, which contained no active antimicrobial, performed as well as or better than all the antimicrobial coatings tested. When the photocatalytic coatings were tested for antifungal activity directly on the substrate surface with increased UV-A exposure, only Ecoreflex exhibited activity. Ecoreflex is marketed for exterior use, and these tests suggested high levels of UV-A from sunlight may be required to achieve antimicrobial effectiveness. Although photocatalytic coatings hold great potential to protect infrastructure and building occupants from harmful mold, this study demonstrated no benefit to using either of the photocatalytic coatings tested over the more traditional antimicrobial coatings or even a quality latex paint in an indoor setting (e.g., low UV-A exposure). However, note that, due to the short nature of the project, all test methods used to evaluate the coatings were accelerated in nature. Extended testing under real-world conditions may be needed to better assess the photocatalytic coatings for long-term resistance to fungal contamination and appropriate Army applicability.

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Acronyms and Abbreviations

Abbreviation	Term
ASTM	American Society for Testing and Materials
ATCC	American Type Culture Collection
BLB	Blacklight Blue
CFM	Cubic Feet per Minute
DoD	Department of Defense
ISO	International Organization for Standardization
PDA	Potato Dextrose
PVC	Polyvinyl Chloride
PMMA	Polymethyl Methacrylate
UV-A	Ultraviolet A
USEPA	U.S. Environmental Protection Agency
VOC	Volatile Organic Compounds

Appendix A: Product Data Sheet and Safety Data Sheets for Coatings Used in this Evaluation

COATINGS - acrylic

ECOREFLEX

Ultra reflective protective coating, self cleaning and photocatalytic

1423602

Self cleaning and photocatalytic liquid coating formulated with water based synthetic resin and special additives. The product provides photocatalytic reaction that achieves degradation of airborne pollutants. *Ecoreflex* guarantees UV rays reflection, lowering the temperature of the support over which it is applied, favoring a high energy saving for air conditioning. Ready to use and suitable to be applied to horizontal, vertical and sloped surface, it has a good adhesion onto bituminous or slated membranes.

ADVANTAGES

- Easy and quick application.
- SELF-CLEANING
- Excellent de-polluting functionality
- High capability to reflect sun rays.
- It contributes to reduce the energetic need for air conditioning during summer, thus favoring energy saving and lowering cities pollution level.
- It reduces Heat Island Effect.
- High elasticity both at low and high temperatures.
- Excellent weathering resistance.
- Excellent re-waterproofing features

APPLICATION FIELD

The product is studied where there is a concentration of pollutants and it is suitable to protect:

- Pitched or flat roof;
 - Horizontal, vertical or scope surfaces.
- It can be used to the following surfaces:
- bituminous or slated membranes in good conditions;
 - concrete surfaces;
 - metal surfaces in combination with *WATstop*;
 - waterproofing system based on synthetic resins.
- Product for outdoor.

YIELD

1,0 kg/m²

COLOUR

White, pastel green, pastel pink, pastel sky blue.

PACKAGING

20 kg or 5 kg plastic bucket.

Pallet:

- 5 kg plastic bucket – 20 boxes (4 pieces each) – 400 kg;
- 20 kg plastic bucket – 48 buckets (960 kg).

STORAGE

Store the product in its original containers perfectly closed, in well ventilated areas, away from sunlight, water and ice, at temperatures between +5°C and +35°C.

Storage time: 24 months.

PREPARATION OF SUPPORT

- The support must be completely hardened, dry and resistant enough and with the adequate sloping to let the water flow.
- In presence of new realised cement substrate, this must be sufficiently dry and cured.
- Substrate temperature must be between +5°C and +35°C.
- The surface must be thoroughly clean, well consolidated, without debris or detaching parts.
- Remove dust, greases and oils washing the surface with water and let dry.
- In case of very dirty or crumbly surface, it is advisable to mechanically clean it.
- For application onto new bituminous membranes which release greases and oils, please make a test to verify the perfect adhesion of the product.
- In case of application to metal surface, remove rust with *Rust Converter* and prime with *WATstop* (see technical data sheets).

Coatings - acrylic

Whereas all indications and recommendations supplied herein are stated to the best of our experience and knowledge, they should nevertheless be considered as indicative only and should be confirmed by exhaustive practical applications. Therefore, before using this product, we recommend in any case to perform preliminary tests with the purpose of verifying the complete suitability for the intended use. In case of uncertainties and doubts contact our technical office. This sheet supersedes any other previously released.

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ORIPLAST REFLEX*Ultra reflective protective coating***Technical Data**

Features		Unit
Yield	1,0	kg/m ²
Aspect	liquid	-
Colour	White, pastel green, pastel pink, pastel sky blue	-
Dilution	do not dilute	-
Waiting time between 1st and 2nd coat (T=20°C; R.H. 40%)	5	hours
Application temperature	+5 /+35	°C
Max humidity	70%	-
Drying time (T=20°C; R.H. 40%)	5	hours
Storage	24 months in original containers and in dry place	months
Packaging	5 kg or 20 kg plastic bucket	kg

Final performances		Units	Regulations	Result
Isopropanol conversion (simulating smog) with broad spectrum lamp Vitalus-Osram (300W)	80% after 24 hours of radiation	-	-	-
Smoke test (yellowing 15 days + 3 hours of UVB rays)	-	-	-	-
Reflection	> 90%	-	-	-
Thermal emission (E)	91%	-	ASTM C1371	-
Solar Reflex Index (SRI)	102%	-	ASTM E1980	-
Surface temperature difference between bituminous membrane – Ecoreflex	~ 48	°C	UNI EN ISO 13786	-
Temperature difference external-internal	34	°C	UNI 10375 UNI EN ISO 13791 UNI EN ISO 13792	-
Waterproofing (positive pressure)	7	Atm	UNI EN 8202/21	-
Weathering test	2000 (>10 years)	hours	UNI EN ISO 11507	-
Resistance to 50 freeze-thaw cycles (-15°C/+15°C)	-	-	UNI EN 202	unchanged
Bend Test	12	mm	ISO 1519	good
Break elongation	327%	-	ISO EN 527-3	-
Adhesion to bituminous membrane Adhesion Test pull – off	> 7,0	Mpa = N/mm ²	ISO 4624 ASTM D4541	excellent

Coatings - acrylic

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ORIPLAST REFLEX

Ultra reflective protective coating

Final performances		Units	Regulations	Result
Adhesion to slated membrane Adhesion Test pull – off	4,3	Mpa = N/mm ²	ISO 4624 ASTM D4541	excellent
Adhesion to galvanized sheet Adhesion Test pull – off	1,7	Mpa = N/mm ²	ISO 4624 ASTM D4541	good
Adhesion to slate Adhesion Test pull – off	2,5	Mpa = N/mm ²	ISO 4624 ASTM D4541	good
Adhesion to polyurethane panel (PU) - Adhesion Test pull – off	1,5	Mpa = N/mm ²	ISO 4624 ASTM D4541	good
Break elongation after 2000 hours of weathering test	166%	-	-	-
Traction resistance after 2000 hours of weathering test	1,12	N/mm ²	-	-
Ponding water resi stance (9 months)	-	-	-	very good
Viscosity (Brookfield viscometer DV-E s04, 6 rpm, T= 20°C, U.R. 75%)	24000	Mpa·s	-	-

* 1680 of weathering test are equal to about 10 years. This equivalence is merely indicative and it may change depending on the climate and the place where the product is applied. The above data, even if carried out according to regulated tests are indicative and they may be change when specific site conditions vary.

MIXING

The product is one component, ready to use. Do not dilute. Before application, mix the product with drill mixer at high speed. Do not add other components.

APPLICATION

1. Apply a first coat of *Ecoflex* by brush, roll or air less to completely cover the entire surface. In case of rain on a non perfect dry product, carefully check the suitability of the next covering.
2. When the first coat is dry, apply a second coat with the same system, taking care to cross the two coats to uniformly cover the surface.

DRYING TIME

At 20°C and 40% of relative humidity level, the product drying time is 5 hours.

- Drying time is influenced by relative humidity level and by temperature and may change significantly.

SUGGESTIONS

- Do not apply at temperatures lower than +10°C or higher than +35°C.
- During summer season apply the product in the cooler hours of the day.
- Do not apply with imminent threat of rainwater or ice, in case of strong fog or relative humidity level higher than 70%.
- Apply the product in sunny areas, because only sun exposure can activate the self cleaning reaction and the degradation of airborne pollutants.
- It does not create a walkable surface, it can be walk over only for periodic maintenance.

CLEANING

Wash tools with water before product hardens.

SAFETY

For the handling, see product safety sheet. Wear means of protection.



Coatings - acrylic

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Technical Data Sheet

KEIM Ecosil-ME with MiNOx-Effect – photocatalytic effect



1. Product description

KEIM Ecosil-ME is a heavy duty, multipurpose interior silicate paint to DIN EN 13 300 (it also meets the requirements of DIN 18 363, 2.4.1, silicate emulsion paint) with the property to reduce pollutants and neutralize odors.

2. Field of application

KEIM Ecosil-ME is particularly suitable for interior walls and ceilings in heavily used areas such as public buildings, hospitals, labs, schools, offices, hotels, restaurants and food storage areas. Suitable substrates include but are not limited to most mineral surfaces, cement and lime plasters, concrete, bricks, plasterboard, glass fiber fabric, MGO board, GFRC, and sound existing acrylic based coatings. Highly absorbent or dusting substrates are pretreated with KEIM Soliprim. KEIM Grundierweiss may advantageously be applied as a first coat in order to equalize differing levels of absorbency and color. When applying colored finishes onto plasterboard surfaces and substrates spot-filled with plaster, an undiluted first coat of KEIM Grundierweiss is absolutely essential (as an alternative coating structure for colored finishes on plasterboard and substrates spot-filled with plaster: consider using KEIM Dolomit Spachtel for spot fills or full coat plaster). KEIM Grundierweiss should not be used on pure gypsum plaster renders (P IVa, b and P Va). KEIM Ecosil-ME is not suitable for surfaces with salt efflorescence, on wood and enamels without proper surface preparation.

3. Product properties

- can be exposed to extreme mechanical loads, highly scrub-resistant
- photocatalytic effect (test report): converts noxious gases, odors, and other organics into

uncritical substances like carbon dioxide and water

- resistant to disinfectants and cleaning agents
- suitable for allergy sufferers (test certificate)
- no solvents
- zero plasticizer content
- safe for foodstuff applications (test certificate)
- easy to touch up
- elevated hiding power
- non-flammable (similar to building material class DIN 4102-A2, according to test certificate)
- resistant to fungal and mold growth,
- LEED - yes

Material characteristics

- org. content: < 5%
- specific weight: approx. 1.55 g/cm³
- VOC content (white or tinted) ASTM D6886: < 1g/l
- Vapor permeability 75 - 85 perms
- Flame spread, according to ASTM E84-05: 0
- Smoke, according to ASTM E84-05: 0
- diffusion-equivalent air-layer thickness: $s_e < 0.01$ m (FPL report) (to DIN EN ISO 7783-2)

Classification acc. to DIN EN 13300

- gloss at 85° (to ISO 2813): dull matt 0.5
- maximum grain size (to EN 21524): fine
- contrast ratio (hiding power) (to ISO 6504-3) (at a yield of 6.5 m²/l): class 1
- wet abrasion resistance (to EN ISO 11998): class 1 acc. to certificate

Color shade

White and KEIM's Palette Exclusive range. Not available in full tone colors. Contact a KEIM representative about the color range for Ecosil-ME. Ecosil-ME can only be factory tinted. Custom color matching upon request.



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TD KEIM Ecosil[®]-ME**4. Application instructions****Application temperature**

Ambient and substrate temperature must not fall below 41 °F (+5 °C).

Substrate preparation

Highly absorbent or dusting substrates should be pretreated with KEIM Soliprim. The mineral substrate must be sound, dry, clean and free of dust, grease, oils, salts and other substances that would prevent bonding. With some colors pure gypsum plasters can cause ghosting due to water soluble gypsum salts and may require sealing the surface before painting.

Application Two-coat system:

KEIM Ecosil-ME may be applied by brush, roller or spraying (nozzle size: 0.64 mm / 0.025 in.). Depending on how drying is progressing, an interval of at least 6 hours should generally be observed between the base and top coat.

Base coat: Dilute KEIM Ecosil-ME with up to 10% KEIM Spezial-Dilution.

Top coat: KEIM Ecosil-ME undiluted.

Consumption

Approximately 300 - 350 Sq.Ft. per gallon plus up to 10% KEIM Spezial-Dilution in first coat. 12.8 fl. oz. of KEIM Spezial-Dilution per gallon of KEIM Ecosil-ME = 10%.

The stated consumption figures are for guidance. Exact values can only be determined by painting test areas on the structure to be coated.

Cleaning of tools

Clean with water immediately after use.

5. Packaging

1 gallon, 2 gallon and 4 gallon containers.

6. Storage

Approx. 12 months in sealed container under cool, frost-free conditions. Protect from heat and direct sunlight.

7. Hazardous substances ordinance class

n/a

8. Transport hazard class

n/a

9. Disposal

EC Waste Code no. 08 01 12

Any residues must be emptied out of containers before recycling.

10. Safety instructions

Cover areas which are not to be coated, especially glass, ceramics and natural stone. Any splashes on surrounding surfaces or traffic areas must be rinsed off immediately with plenty of water. Protect the eyes and skin from splashes of paint. Do not eat or drink during application. Keep out of reach of children.

Product code: M-SK 01

The stated values and properties are the result of extensive development work and practical experience. Our recommendations for application, whether given verbally or in writing, are intended to provide assistance in the selection of our products and do not establish a contractual relationship. In particular, they do not release those purchasing and applying our products from the duty of establishing for themselves, with due care, the suitability of our products for the intended application. Standard building industry practices must be complied with. We retain the right to make modifications to improve the products or their application. This edition supersedes all earlier editions.



KEIM MINERAL COATINGS
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www.keim.com Keim-info@keim.com

AfterShock

Fungicidal Coating

Product Description

AfterShock is an EPA registered antimicrobial coating designed to kill residual mold and mildew remaining after pre-cleaning contaminated surfaces. AfterShock also inhibits the future growth and spread of mold and mildew on the cured film surface in residential and institutional buildings. This extremely durable, easy to apply, 100% acrylic sealant offers the ultimate in durability in combination with excellent fungicidal characteristics to address mold growth from water damage. AfterShock is recommended for use on interior wall surfaces such as plaster, wallboard, drywall, concrete, masonry block, wood, primed metal and galvanized metal. AfterShock is also recommended for use on interior wood framing, primed metal, concrete, and wallboard inside the wall cavity. Do not use for HVAC system applications.

8390-White

Application Information

SURFACE PREPARATION

AfterShock is supplied ready to use. Stir thoroughly. Do not mix with other coatings, solvents or colors in oil. Remove damaged materials and clean surfaces. Surface must be free of dust, mildew, mold, dirt, grease, loose paint, oil, glue size, calcimine, wax, soap and other surface contamination. Patch surface irregularities with an appropriate patching compound. AfterShock is self-priming over bare gypsum drywall, composition board, ceiling tile and concrete. Do not apply when air or surface temperature is below 50°F or when drying conditions are poor. Use adequate ventilation during application.

DRYWALL - Joint cement should be sanded smooth, but avoid abrading the paper.

FERROUS METAL - Clean, then prime with Fiberlock IAQ™ 4000 acrylic DTM primer.

WOOD - Seal knots and stains with Fiberlock IAQ 5000 stain-blocking primer.

MASONRY BLOCK - Apply one coat of Fiberlock IAQ 3000 acrylic block filler if a denser surface is desired.

APPLICATION TOOLS

Apply AfterShock with brush, roller or airless spray equipment. If using airless spray equipment, AfterShock can be successfully applied with a .017-.021 tip setting. When applying with a sprayer, wear a NIOSH approved respirator with any R, P, N or HE filter.

PRODUCT APPLICATION

Remove gross filth or heavy soil. For heavily soiled areas, a pre-cleaning step is required. Apply AfterShock generously and

uniformly by brush, roller or airless spray and ensure that the surface is completely coated. Allow to air dry. Clean and inspect regularly for damage to coating film - reapply if cured coating film becomes damaged. AfterShock will kill residual mold and mildew on the surface, and then will prevent the growth of mold and mildew on the surface of the cured film.

CLEANUP

Clean tools and drippings with warm soapy water before AfterShock dries.

FIRST AID

Have the product label or SDS with you when calling a poison control center or doctor, or going for treatment.

IF IN EYES: Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a poison control center or doctor for further treatment advice.

IF INHALED: Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth, if possible. Call a poison control center or doctor for further treatment advice.

IF SWALLOWED: Do not induce vomiting unless told to do so by a poison control center or doctor. Do not give any liquid to the person. Do not give anything by mouth to an unconscious person.

IF ON SKIN OR CLOTHING: Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes.

Properties

Product Specifications

Solids by Weight ± 2%:	42.0%
Solids by Volume ± 2%:	32.7%
Viscosity at 70°F:	95-100 Krebs Units
Specular Gloss:	60° ± 5 @ 60°
Flash Point:	Non-combustible
Shelf Life:	36 Months Min. (Original Sealed Container)
Calculated VOC:	100 grams/liter

Coverage

Smooth Surfaces:	250-400 ft ² /gal
Porous Surfaces:	150-300 ft ² /gal

Drying Times (@ 70 - 77°F, 50% R.H.)

To Touch:	1 hour
To Recoat:	4 hours
Minimum Application Temp:	50° (10°C)

Available Package Sizes

1 & 5 gallon containers	
Weight Per Gallon ± .5 lbs:	9.7 lbs/gal

Product Testing

EPA Registration Number:	73884-1
EPA Est. Number:	73884-MA-1
Water Vapor Permeance:	2.9 perms



AfterShock

PRODUCT DATA SHEET

Fungicidal Coating

8390-White

Application Information

PRECAUTIONS

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

Do not contaminate water, food or feed by storage or disposal.

PESTICIDE STORAGE: Close container after each use. Keep from freezing. Store in a dry place at temperatures between 40°F (4.5°C) and 90°F (32°C).

PESTICIDE DISPOSAL: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility. **CONTAINER DISPOSAL:** Triple rinse (or equivalent). Then offer for recycling or reconditioning, or puncture and dispose of in a sanitary landfill, or incineration, or, if allowed by state and local authorities, by burning. If burned, stay out of smoke.

**FOR MEDICAL ASSISTANCE, CALL YOUR LOCAL
POISON CONTROL CENTER or 800-222-1222**

PRECAUTIONARY STATEMENTS

HAZARDOUS TO HUMANS

CAUTION!

KEEP OUT OF REACH OF CHILDREN.

Do not take internally. Close container after each use.

Keep from freezing

Store between 40°F (4.5°C) and 90°F (32°C)

24 hour Emergency "CHEM-TEL" - 800.255.3924

CAUTION

Harmful if swallowed or inhaled. Avoid breathing spray mist. Avoid contact with skin, eyes, or clothing. Wash thoroughly with soap and water after handling. Remove contaminated clothing before reuse. When applying with a sprayer, applicator should wear a dust/mist-filtering respirator (MSHA/NIOSH approval number prefix TC-21C) or a NIOSH approved respirator with any R, P, N, or HE filter. Do not apply this product in or on electric equipment due to the possibility of shock hazard. CHECK WITH ALL LOCAL, STATE, AND FEDERAL REGULATIONS BEFORE BEGINNING WORK OR USING THIS PRODUCT. FIX THE SOURCE OF ANY MOISTURE PROBLEMS PRIOR TO REMEDIATION. DO NOT ATTEMPT TO SALVAGE DAMAGED OR STRUCTURALLY UNSOUND BUILDING MATERIALS. CONSULT WITH A QUALIFIED PROFESSIONAL TO PERFORM A THOROUGH INSPECTION AND SUPPLY WORK SPECIFICATIONS APPROPRIATE TO THE PROJECT.


For Technical Information call 800.342.3755

These suggestions and data are based on information we believe to be reliable. They are offered in good faith, but without guarantee, as conditions and methods of use of this product are beyond our control. Neither ICP Construction, Inc., nor its agents shall be responsible for the use or results of use of this product or any injury, loss or damage, direct or consequential. We recommend that the prospective user determine the suitability of this product for each specific project and for the health and safety of personnel working in the area.

AfterShock, the AfterShock Logo and other marks in this literature are trademarks of ICP Construction, Inc.

REV 6.22.18

150 Dascomb Rd • Andover, MA 01810 • www.fiberlock.com • 800.342.3755

	TECHNICAL DATA	ZNR-22
	ZINSSER® MOLD KILLING PRIMER EPA Reg. No. 87469-1-69587 – EPA Est. No. 69587-NJ-002	

DESCRIPTION AND USES

Zinsser® Mold Killing Primer is a water-based EPA registered fungicidal protective coating that can be used to paint over and kill all existing mold, mildew, moss, fungi, odor causing bacteria and any other fungal organisms*. The Mold Killing Primer contains an EPA registered antimicrobial to prevent the growth of mold, mildew and other fungal organisms on the paint film. Mold Killing Primer also aides in covering residual microbiological and fungal stains.

Mold Killing Primer is for use on non-porous interior and exterior, residential, commercial, and industrial applications and can be applied in factories, warehouses, storage facilities, refrigerated storage facilities, office buildings, residential living, schools, hospitals, veterinary care facilities, elderly care facilities, prisons and correction facilities, wash houses, restaurants, fitness centers and locker rooms, attics, basements, window frames, bathrooms, wall cavities, base-boards, sub-floors and table tops. Mold Killing Primer can be used with any topcoat, and is ideal with Zinsser PERMA-WHITE®. Not recommended for new or unpainted aluminum, metal or vinyl siding.

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Check with all local, state and federal regulations prior to using or working or using this product. Fix the source of any moisture problems prior to remediation. Do not attempt to salvage damaged or structurally unsound building materials. Consult a qualified professional to perform a thorough inspection and supply work specifications appropriate to the project.

PRODUCTS

SKU	Description
276049	1-Gallon
276087	1-Quart
276088	5-Gallon

PRODUCT APPLICATION

SURFACE PREPARATION

For applications that have existing wet, slimy, heavy soiled, gross filth, overgrowth or loose material on the substrate a pre-cleaning step is required. Physically or mechanically remove gross filth, heavy soil, overgrowth or loose material including dirt, grease, and oily films before application and ensure the substrate is free of slime or excessive moisture to ensure long-term adhesion and product performance, particularly on exterior surfaces. If mold or mildew needs to be removed prior to application remove with a mildew remover that is EPA registered and let dry. Eye, skin and NOISH approved respiratory protection is highly recommended. Patch surface irregularities with appropriate patching compounds.

PRODUCT APPLICATION (cont.)

WARNING! If you scrape, sand or remove old paint, you may release lead dust. LEAD IS TOXIC. EXPOSURE TO LEAD DUST CAN CAUSE SERIOUS ILLNESS, SUCH AS BRAIN DAMAGE, ESPECIALLY IN CHILDREN. PREGNANT WOMEN SHOULD ALSO AVOID EXPOSURE. Wear a NIOSH-Approved respirator to control lead exposure. Clean up carefully with a HEPA vacuum and a wet mop. Before you start, find out how to protect yourself and your family by contacting the National Lead Information Hotline at 1-800-424-LEAD or log on to www.epa.gov/lead.

APPLICATION

Mold Killing Primer is a ready to use product. Do not thin, do not dilute and do not mix with water or other chemicals or other paints. Mix thoroughly. Do not apply when air or surface temperature is below 50°F (10°C) or when drying conditions are poor. Use adequate ventilation during application.

Use a brush, roller, or airless sprayer to apply. Follow the manufacturer's instructions when using spray equipment. For airless spraying use a 0.017" to 0.019" tip at 2000 to 2500 psi. Coverage is dependant on substrate porosity and surface smoothness. Apply generously and uniformly, ensuring that the surface is completely coated. Allow to air dry. For heavy water stained areas, prime with Mold Killing Primer and allow it to dry. Follow with a Zinsser stain blocking primer such as BIN, BIN Advanced or Cover Stain.

DRY TIME

Mold Killing Primer dries to the touch in 30 minutes and can be recoated in 1 hour. For optimal protection, apply topcoat within 72 hours of application. Full adhesion and hardness develops in 7 days.

LIMITATIONS

Mold Killing Primer is not designed for application to floors or decks or to surfaces subject to immersion or prolonged contact with water.

CLEAN-UP

Clean all application tools with warm soapy water. Wipe up spills immediately with a clean damp cloth. Follow equipment manufacturer's directions to clean spray equipment. See label for proper container disposal.

TECHNICAL DATA		
ZINSSER® MOLD KILLING PRIMER		
PHYSICAL PROPERTIES		
MOLD KILLING PRIMER		
Physical Properties		
Resin Type	Styrene Acrylic	
Pigment Type	Calcium Carbonate	
Solvents	Water, Ethylene Glycol	
Weight	Per Gallon	10.4 lbs.
	Per Liter	1.25 kg
Solids	By Weight	50.9%
	By Volume	38.9%
Volatile Organic Compounds	<100 g/l	
Recommended Dry Film Thickness (DFT) per Coat	1.0-2.0 mils (25-50 μ)	
Wet Film to Achieve DFT (Unthinned material)	2.5-5.0 mils (62.5-125 μ)	
Theoretical Coverage at 1 mil DFT (25 μ)	624 sq.ft./gal. (15.4 m ² /l)	
Practical Coverage at Recommended DFT (assume 15% material loss)	Approximately 400-450 sq.ft./gal. (9.8-11.0 m ² /l) depending on application method and surface porosity	
Dry Times at 70°F (21°C) and 50% Relative Humidity	Touch	30 minutes
	Handle	1 hour
	Recoat	1 hour
	Full Cure	7 days
Shelf Life	1 year	
Flash Point	>200°F (93°C)	
Storage	Protect from freezing. Store indoors at 40-80°F (4-26°C)	
Disposal	See label for proper container disposal	
Safety Information	For additional information, see SDS	

The technical data and suggestions for use contained herein are correct to the best of our knowledge, and offered in good faith. The statements of this literature do not constitute a warranty, express, or implied, as to the performance of these products. As conditions and use of our materials are beyond our control, we can guarantee these products only to conform to our standards of quality, and our liability, if any, will be limited to replacement of defective materials. All technical information is subject to change without notice.



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Form: GDH-252
Rev.: 120616



Sporicidin® Mold Resistant Coatings

Easy to use coating prevents the growth of mold on the coating film when applied to porous and/or non porous surfaces.

Sporicidin® Mold Resistant Coating is an easy-to-use, water-based permanent coating that incorporates a unique zero VOC, EPA registered antimicrobial that prevents the growth of mold on the coating film. Developed for high moisture areas, this product forms a dehydration finish that does not allow moisture penetration, thus preventing the growth of mold on the film. The quality of the product, along with the anti-abrasion* and anti-scratch qualities, exceed the performance requirements of the following microbiological resistant tests: ASTM D3273, D3274.

Sporicidin Mold Resistant Coatings can be used on any new or existing building material before, during, or after installation. It quickly penetrates and adheres to porous and non-porous surfaces, providing a stain-blocking coating that will not blister, crack, or chip and restores the integrity of damaged materials.



PERFORMANCE CHARACTERISTICS:

- Mold resistance on the film
- Special UV detectable pigment for warranty verification
- Non-leaching and non-toxic
- Excellent longevity
- Bonds to organic and inorganic surfaces
- Superior moisture prevention
- Breathable and paintable
- Designed to provide a uniform primer or can be left as the top coat
- Features phenomenal hiding and enamel holdout
- Nanotechnology provides excellent durability and adhesion
- Provides protection from water penetration
- Seals water extractives and tannins in redwood and cedar
- Dry to touch time: 30 min. to 60 min. depending on product used, temperature and humidity
- Shelf life: three years
- Air Quality and Management District (AQMD) and VOC compliant

IT CAN BE APPLIED TO:

- Lumber
- Particle board
- Walls
- Ceilings
- Subfloors
- Ductwork
- Wood
- Drywall
- Mineral substrates**

** It aids in deodorizing and eliminating odors while providing a paint-like film on interior and exterior surfaces that can be sanded and recoated without the obnoxious fumes like competitive products.

** When applied correctly, the film bonds to the surface and lasts for a long period of time; however, abrasion can eventually harm the film when the surface is not cared for properly.*

Note: Always test on inconspicuous areas prior to full application.

SPO19
120514



P.O. Box 530 • Spartanburg, SC 29304 USA
Tel: +1-864-503-8333
Toll Free (US, Canada, PR): 1-800-289-5762
www.sporicidin.com • sporicidin@contecinc.com



Sporicidin® Mold Resistant Coatings

Easy to use coating prevents the growth of mold on porous and non porous surfaces.

SELECT THE RIGHT PRODUCT		
Part Number	Coverage	Color
MRC-79C	Up to 35 sq.ft./can	Clear
MRC-80	Up to 1,000 sq.ft./gallon	Clear
MRC-100	Up to 400 sq.ft./gallon	White

FURTHER QUESTIONS?

Technical Information is also available on these and other Sporicidin® Brand Products.

Ask your sales rep for more information.

Part No.	Description	Packaging
MRC-79C	Sporicidin Mold Resistant Coating Spray, 12 fl. Oz. (0.35L) container, Clear, UV Indicator	12 cans/case
MRC-80-1	Sporicidin Mold Resistant Coating, 1 Gallon (3.7L) container, Clear, UV Indicator	4 containers/case
MRC-80-5	Sporicidin Mold Resistant Coating, 5 Gallon (18.9L) container, Clear, UV Indicator	1 container/case
MRC-100-1	Sporicidin Mold Resistant Coating, 1 Gallon (3.78L) container, White	4 containers/case
MRC-100-5	Sporicidin Mold Resistant Coating, 5 Gallon (18.9L) container, White	1 container/case



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 Toll Free (US, Canada, PR): 1-800-289-5762
 Europe: +33 297437690
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102.10

SuperPaint®
Exterior Latex Satin

A89-100/1000 Series



**SHERWIN
WILLIAMS.**

CHARACTERISTICS	COMPLIANCE	SPECIFICATIONS																																					
<p>SuperPaint Exterior, with resistance to early dirt pick up, provides outstanding performance on properly prepared aluminum and vinyl siding, wood, hardboard, masonry, cement, brick, block, stucco, and metal down to a surface and air temperature of 35°F.</p> <p>VinylSafe™ paint colors allow you the freedom to choose from 100 color options, including a limited selection of darker colors formulated to resist warping or buckling when applied to a sound, stable vinyl substrate.</p> <p>Color: Most colors To optimize hide and color development, always use the recommended P-Shadow primer</p> <p>Coverage: 350 - 400 sq ft/gal @ 4 mils wet; 1.5 mils dry</p> <p>Drying Time, @ 50% RH: @ 35-45°F @ 45°F + Touch: 2 hour 2 hours Recoat: 24-48 hours 4 hours Drying and recoat times are temperature, humidity, and film thickness dependent</p> <p>Finish: 10-20 units @ 80°</p> <p>Tinting with CCE:</p> <table border="0"> <tr> <td>Base</td> <td>oz/gal</td> <td>Strength</td> </tr> <tr> <td>Extra White</td> <td>0-6</td> <td>SherColor</td> </tr> <tr> <td>Deep Base</td> <td>4-12</td> <td>SherColor</td> </tr> <tr> <td>Ultradeep Base</td> <td>10-12</td> <td>SherColor</td> </tr> <tr> <td>Light Yellow</td> <td>2-12</td> <td>SherColor</td> </tr> </table> <p style="text-align: center;">Extra White A89W01151 (may vary by base)</p> <p>VOC (less exempt solvents): <50 g/L; <0.42 lb/gal</p> <p>As per 40 CFR 59.406</p> <p>Volume Solids: 38 ± 2%</p> <p>Weight Solids: 49 ± 2%</p> <p>Weight per Gallon: 10.19 lb</p> <p>Flash Point: N/A</p> <p>Vehicle Type: 100% Acrylic</p> <p>Shelf Life: 36 months unopened</p> <p>WVP Perms (US) 28.14 grains/(hr ft² in Hg)</p> <p>Mildew Resistant This coating contains agents which inhibit the growth of mildew on the surface of this coating film.</p>	Base	oz/gal	Strength	Extra White	0-6	SherColor	Deep Base	4-12	SherColor	Ultradeep Base	10-12	SherColor	Light Yellow	2-12	SherColor	<p>As of 05/29/2019, Complies with:</p> <table border="0"> <tr> <td>OTC</td> <td>Yes</td> </tr> <tr> <td>OTC Phase II</td> <td>Yes</td> </tr> <tr> <td>SCAQMD</td> <td>Yes</td> </tr> <tr> <td>CARB</td> <td>Yes</td> </tr> <tr> <td>CARB SCM 2007</td> <td>Yes</td> </tr> <tr> <td>Canada</td> <td>Yes</td> </tr> <tr> <td>LEED® v4&v4.1 Emissions</td> <td>N/A</td> </tr> <tr> <td>LEED® v4&v4.1 VOC</td> <td>Yes</td> </tr> <tr> <td>EPD-Certified</td> <td>N/A</td> </tr> <tr> <td>MIR-Certified</td> <td>N/A</td> </tr> <tr> <td>MPI</td> <td>Yes</td> </tr> </table> <p style="text-align: center;">APPLICATION</p> <p>When the air temperature is at 35°F, substrates may be colder; prior to painting, check to be sure the air, surface, and material temperature are above 35°F and at least 5°F above the dew point. Avoid using if rain or snow is expected within 2-3 hours.</p> <p>Do not apply at air or surface temperatures below 35°F or when air or surface temperatures may drop below 35°F within 48 hours.</p> <p>No reduction necessary.</p> <p>Brush Use a nylon/polyester brush.</p> <p>Roller Use a 3/8" - 3/4" nap synthetic cover.</p> <p>Spray—Airless Pressure.....2000 psi Tip......015"-.019"</p>	OTC	Yes	OTC Phase II	Yes	SCAQMD	Yes	CARB	Yes	CARB SCM 2007	Yes	Canada	Yes	LEED® v4&v4.1 Emissions	N/A	LEED® v4&v4.1 VOC	Yes	EPD-Certified	N/A	MIR-Certified	N/A	MPI	Yes	<p>SuperPaint Exterior can be self-priming when used directly over existing coatings, or bare drywall, plaster and masonry (with a cured pH of less than 9). The first coat acts like a coat of primer and the second coat provides the final appearance and performance. Please note that some specific surfaces require specialized treatment.</p> <p>Aluminum & Aluminum Siding¹, Galvanized Steel¹, Vinyl Siding 2 cts. SuperPaint Exterior Latex Concrete Block, CMU, Split face Block 1 ct. Loxon Acrylic Block Surfaer 2 cts. SuperPaint Exterior Latex</p> <p>Brick 1 ct. Loxon Conditioner² 2 cts. SuperPaint Exterior Latex Cement Composition Siding/Panels 1 ct. Loxon Concrete & Masonry Primer² or Loxon Conditioner² 2 cts. SuperPaint Exterior Latex</p> <p>Stucco, Cement, Concrete 1 ct. Loxon Concrete & Masonry Primer² 2 cts. SuperPaint Exterior Latex</p> <p>Plywood 1 ct. Exterior Latex Wood Primer 2 cts. SuperPaint Exterior Latex</p> <p>Wood (Cedar, Redwood)³ 1 ct. Exterior Oil-Based Wood Primer² 2 cts. SuperPaint Exterior Latex</p> <p>¹ On large expanses of metal siding, the air, surface, and material temperatures must be 50°F or higher. ² Not for use at temperatures under 50°F. See specific primer label for that product's application conditions. ³ Knots and some woods, such as redwood and cedar, contain a high amount of tannin, a colored wood extract. For best results on these woods, use a coat of Exterior Oil-Based Wood Primer.</p> <p>Other primers may be appropriate. Standard latex primers cannot be used below 50°F. See specific primer label for that product's application conditions.</p> <p>When repainting involves a drastic color change, a coat of primer will improve the hiding performance of the topcoat color.</p>
Base	oz/gal	Strength																																					
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CARB SCM 2007	Yes																																						
Canada	Yes																																						
LEED® v4&v4.1 Emissions	N/A																																						
LEED® v4&v4.1 VOC	Yes																																						
EPD-Certified	N/A																																						
MIR-Certified	N/A																																						
MPI	Yes																																						

SuperPaint®
Exterior Latex Satin

<u>SURFACE PREPARATION</u>	<u>SURFACE PREPARATION</u>	<u>CAUTIONS</u>
<p>WARNING! Removal of old paint by sanding, scraping or other means may generate dust or fumes that contain lead. Exposure to lead dust or fumes may cause brain damage or other adverse health effects, especially in children or pregnant women. Controlling exposure to lead or other hazardous substances requires the use of proper protective equipment, such as a properly fitted respirator (NIOSH approved) and proper containment and cleanup. For more information, call the National Lead Information Center at 1-800-424-LEAD (in US) or contact your local health authority.</p> <p>Remove all surface contamination by washing with an appropriate cleaner, rinse thoroughly and allow to dry. Scrape and sand peeled or checked paint to a sound surface. Sand glossy surfaces dull. Seal stains from water, smoke, ink, pencil, grease, etc. with the appropriate primer/sealer. Recognize that any surface preparation short of total removal of the old coating may compromise the service length of the system.</p> <p>Aluminum and Galvanized Steel Wash to remove any oil, grease, or other surface contamination. All corrosion must be removed with sandpaper, wire brush, or other abrading method.</p> <p>Caulking Gaps between windows, doors, trim, and other through-wall openings can be filled with the appropriate caulk after priming the surface.</p> <p>Cement Composition Siding/Panels Remove all dirt, dust, grease, oil, loose particles, laitance, foreign material, and peeling or defective coatings. Allow the surface to dry thoroughly. If the surface is new, test it for pH, if the pH is higher than 9, prime with Loxon Concrete & Masonry Primer.</p> <p>Mildew Prior to attempting to remove mildew, it is always recommended to test any cleaner on a small, inconspicuous area prior to use. Bleach and bleaching type cleaners may damage or discolor existing paint films. Bleach alternative cleaning solutions may be advised. Mildew may be removed before painting by washing with a solution of 1 part liquid bleach and 3 parts water. Apply the solution and scrub the mildewed area. Allow the solution to remain on the surface for 10 minutes. Rinse thoroughly with water and allow the surface to dry before painting. Wear protective eyewear, waterproof gloves, and protective clothing. Quickly wash off any of the mixture that comes in contact with your skin. Do not add detergents or ammonia to the bleach/water solution.</p>	<p>Masonry, Concrete, Cement, Block All new surfaces must be cured according to the supplier's recommendations—usually about 30 days. Remove all form release and curing agents. Rough surfaces can be filled to provide a smooth surface. If painting cannot wait 30 days, allow the surface to cure 7 days and prime the surface with Loxon Concrete & Masonry Primer. Cracks, voids, and other holes should be repaired with an elastomeric patch or sealant.</p> <p>Steel Rust and mill scale must be removed using sandpaper, wire brush, or other abrading method. Bare steel must be primed the same day as cleaned.</p> <p>Stucco Remove any loose stucco, efflorescence, or laitance. Allow new stucco to cure at least 30 days before painting. If painting cannot wait 30 days, allow the surface to dry 7 days and prime with Loxon Concrete & Masonry Primer. Repair cracks, voids, and other holes with an elastomeric patch or sealant.</p> <p>*Vinyl or other PVC Building Products Clean the surface thoroughly by scrubbing with warm, soapy water. Rinse thoroughly, prime with appropriate white primer. Do not paint vinyl with any color darker than the original color or having a Light Reflective Value (LRV) of less than 56 unless VinylSafe® Colors are used. If VinylSafe colors are not used the vinyl may warp. Follow all painting guidelines of the vinyl manufacturer when painting. Only paint properly installed vinyl siding. Deviating from the manufacturer's painting guidelines may cause the warranty to be voided.</p> <p>Wood, Plywood, Composition Board Clean the surface thoroughly then sand any exposed wood to a fresh surface. Patch all holes and imperfections with a wood filler or putty and sand smooth. All new and patched areas must be primed. Knots and some woods, such as redwood and cedar, contain a high amount of tannin, a colored wood extract. If applied to these bare woods, it may show some staining. If staining persists, spot prime severe areas with 1 coat of Exterior Oil-Based Wood Primer prior to using.</p>	<p>For exterior use only. Protect from freezing. Non-photochemically reactive. Not for use on floors.</p> <p>Before using, carefully read CAUTIONS on label.</p> <p>ZINC Use only with adequate ventilation. To avoid overexposure, open windows and doors or use other means to ensure fresh air entry during application and drying. If you experience eye watering, headaches, or dizziness, increase fresh air, or wear respiratory protection (NIOSH approved) or leave the area. Avoid contact with eyes and skin. Wash hands after using. Keep container closed when not in use. Do not transfer contents to other containers for storage. FIRST AID: In case of eye contact, flush thoroughly with large amounts of water. Get medical attention if irritation persists. If swallowed, call Poison Control Center, hospital emergency room, or physician immediately. WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm. DO NOT TAKE INTERNALLY. KEEP OUT OF THE REACH OF CHILDREN.</p> <p>HOTW 05/28/2019 A89W01151 42 39 FRC,SP, KOR, Viet</p> <p><u>CLEANUP INFORMATION</u></p> <p>Clean spills, splatters, hands and tools immediately after use with soap and warm water. After cleaning, flush spray equipment with a compliant cleanup solvent to prevent rusting of the equipment. Follow manufacturer's safety recommendations when using solvents.</p>
<p>The information and recommendations set forth in this Product Data Sheet are based upon tests conducted by or on behalf of The Sherwin-Williams Company. Such information and recommendations set forth herein are subject to change and pertain to the product offered at the time of publication. Consult your Sherwin-Williams representative or visit www.paintdocs.com to obtain the most current version of the PDS and/or an SDS.</p>		

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14. ABSTRACT New buildings are being constructed and existing buildings retrofitted to be more energy efficient to meet increasingly stringent Department of Defense (DoD) energy standards. Although these standards save energy and lower operational costs, they also limit fresh air within a structure and can cause a buildup of harmful substances in indoor environments. Of particular concern are molds, which can put building occupants at risk and damage infrastructure. One possible solution to this increasing Army problem is to coat building materials with photocatalytic paints, which have the ability to both destroy microorganisms as well as the toxic byproducts they produce. This work compared two next-generation photocatalytic coatings against three more traditional antimicrobial-infused coatings for their ability to resist fungal contamination using three accelerated test conditions. Under each test condition the photocatalytic coatings were found to perform poorly compared to the antimicrobial-infused coatings. Moreover, the control coating, which contained no active antimicrobial (standard latex paint), performed as well as or better than all the antimicrobial coatings tested. This suggested that there may be little benefit to using antimicrobial coatings to inhibit fungal colonization over a standard latex paint; however, further testing is required to confirm this perception.					
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