

Testing Antimicrobial Cleaner Efficacy on Gypsum Wallboard Contaminated with *Stachybotrys chartarum*

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Abstract

Goal, Scope and Background. Reducing occupant exposure to indoor mold is the goal of this research, through the efficacy testing of antimicrobial cleaners. Often mold contaminated building materials are not properly removed, but instead surface cleaners are applied in an attempt to alleviate the problem. The efficacy of antimicrobial cleaners to remove, eliminate or control mold growth on surfaces can easily be tested on non-porous surfaces. However, the testing of antimicrobial cleaner efficacy on porous surfaces, such as those found in the indoor environment such as gypsum board can be more complicated and prone to incorrect conclusions regarding residual organisms. The mold *Stachybotrys chartarum* has been found to be associated with idiopathic pulmonary hemorrhage in infants and has been studied for toxin production and its occurrence in water damaged buildings. Growth of *S. chartarum* on building materials such as gypsum wallboard has been frequently documented.

Methods. Research to control *S. chartarum* growth using 13 separate antimicrobial cleaners on contaminated gypsum wallboard has been performed in laboratory testing. Popular brands of cleaning products were tested by following directions printed on the product packaging.

Results. A variety of gypsum wallboard surfaces were used to test these cleaning products at high relative humidity. The results indicate differences in antimicrobial efficacy for the six month period of testing.

Discussion. Results for the six types of GWB surfaces varied extensively. However, three cleaning products exhibited significantly better results than others. Lysol All-Purpose Cleaner-Orange Breeze (full strength) demonstrated results which ranked among the best in five of the six surfaces tested. Both Borax and Orange Glo Multipurpose Degreaser demonstrated results which ranked among the best in four of the six surfaces tested.

Conclusion. The best antimicrobial cleaner to choose is often dependent on the type of surface to be cleaned of *S. chartarum* contamination. For Plain GWB, no paint (see Table 3), the best cleaners were Borax, Lysol All-Purpose Cleaner-Orange Breeze (full strength), Orange Glo Multipurpose Degreaser, and Fantastik Orange Action.

Recommendations and Perspectives. These results are not meant to endorse the incomplete removal of mold contaminated building materials. However, it is recognized that complete removal may not always be possible and solutions to control mold regrowth may contribute to reduced occupant exposure. Current recommendations of removal and replacement of porous building materials should be followed.

It is not the intension of this discussion to endorse any product. Reporting on the performance of these products under the stated conditions was and remains the only purpose.

Keywords: mold; antimicrobial efficacy; cleaners; gypsum wallboard; biocontaminant; *Stachybotrys chartarum*

Introduction

The past twenty years have brought the recognition that an important factor in the health of people in indoor environments is the dampness of the buildings in which they live and work (Dearborn, D. G. et. al. 1999; Vesper, S. J., and Vesper, M. J., 2002; Vesper, S. J., 2000). Furthermore, it is now appreciated that the principal biological contaminants responsible for the health problems in such buildings are fungi rather than bacteria or viruses (Dearborn, D. G. et. al. 1999; Vesper, S. J., and Vesper, M. J., 2002; Vesper, S. J., et. al. 2000; Scheel, C. M., 2000). Although traditionally, fungi in this context have been viewed as allergens (and in unusual circumstances, pathogens), data have accumulated to show that the adverse health effects resulting from inhalation of fungal spores are due to multiple factors (Sudakin, D. L., 2000). One factor associated with certain fungi are small molecular toxins (mycotoxins) produced by these fungi. Traditionally, mycotoxins are held to be important in human and animal health because of their production by toxigenic fungi associated food and feed. However, mycotoxins tend to concentrate in fungal spores, and thus present a potential hazard to those inhaling airborne spores. Toxigenic spores strongly affect alveolar macrophage function and pose a threat to those exposed. Reports have indicated that *S. chartarum*, *A. versicolor*, and several toxigenic species of *Penicillium* are potentially hazardous, especially when the air-handling systems have become heavily contaminated (Vesper, S. J., et. al. 2000; Scheel, C. M., 2001; Sudakin, D. L., 2000; Murtoniemi, T., et. al. 2001).

One of the toxigenic fungi found in wet buildings is *S. chartarum*, a fungus known to produce the very potent cytotoxic macrocyclic trichothenes along with a variety of immunosuppressants and endothelin receptor antagonists mycotoxins (Dearborn, D. G. et. al. 1999; Vesper, S. J., and Vesper, M. J., 2002; Vesper, S. J., 2000). Infants have been admitted to Case Western University Hospital in Cleveland in very grave condition expelling blood from their nose and mouth from pulmonary hemorrhage (PH) (Dearborn, D. G. et. al. 1999; Vesper, S. J., and Vesper, M. J., 2002; Vesper, S. J., 2000). There have been 45 cases of PH in young infants, of which 16 have died.

Stachybotrys requires water soaked cellulose to grow and has been found in homes where there had been water damage from flooding, plumbing leaks, or roof leaks involving wood or paper products (e.g., insulation, gypsum board, ceiling tile). The spores of this fungus contain mycotoxins which appear to be particularly toxic to the rapidly growing lungs of infants (Dearborn, D. G. et. al. 1999; Vesper, S. J., and Vesper, M. J., 2002; Vesper, S. J., 2000; Scheel, C. M., 2001; Sudakin, D. L., 2000; Murtoniemi, T., et. al. 2001). Although not widely found, *Stachybotrys* has been studied for the last 20 years. The following is documented: (1) *S. chartarum* produces toxigenic spores that are potentially hazardous, (2) the prevalence of *S. chartarum* contamination in indoor environments is unknown, and (3) currently there are no Environmental Protection Agency (EPA) regulations or guidelines for evaluating potential health risks of *S. chartarum* contamination and remediation (Dearborn, D. G. et. al. 1999; Vesper, S. J., and Vesper, M. J., 2002; Vesper, S. J., 2000; Scheel, C. M., 2001; Sudakin, D. L., 2000; Murtoniemi, T., et. al. 2001).

S. chartarum will grow in saturated air conditions (100 percent RH) without any additional moisture. At an RH of 97 percent and below, wetting is necessary for the growth of *S. chartarum* (Menetrez, M. Y., 2004). Variations in the type of gypsum wallboard (GWB) have little effect on growth. Wood boards and plywood that have been soaked in water and allowed to be exposed to saturated RH conditions can grow *S. chartarum*.

Manufactured gypsum board which becomes wet and allowed to remain wet for a protracted length of time is susceptible to mold growth regardless of vinyl covering (Menetrez, M. Y., 2004).

Methods of testing antimicrobial efficacy are needed to evaluate differences in products which are sold for cleaning and disinfecting surfaces to remove mold (Menetrez, M. Y., and Foarde, K. K., 2002). Successful remediation of mold infested surfaces must remove existing mold and prevent regrowth over time, regardless of fluctuations in RH or variations in gypsum wallboard building products.

To demonstrate the efficacy of cleaning products that prevent the return of mold, 13 different cleaning products (one product was tested both diluted and full strength) were selected for their wide availability, and the product description which recommended its use for disinfecting surfaces, specifically removing mold and mildew (see Table 1, Cleaners Tested). Each product was tested following the directions on the package and the recommended concentration. Six varieties of surfaces were used to evaluate *S. chartarum* growth. The surfaces were constructed over standard GWB, they were:

1. Plain GWB, no paint,
2. Vinyl (100 percent vinyl) covered GWB,
3. GWB with vinyl coated wallpaper removed before cleaning and replaced,

4. GWB with vinyl coated wallpaper not removed before cleaning,
5. GWB with oil-based paint,
6. GWB with acrylic (latex) paint.

The object of this research was to test the antimicrobial efficacy of these cleaning and disinfectant products for removing and preventing, or restricting growth of *S. chartarum* growth on the six varieties of GWB surfaces listed above, and with variations in RH.

1 Materials and Methods:

1.1 Products tested

A total of 14 sets of experiments were conducted on cleaning products [13 separate cleaning products (see Table 1) of which one product was tested both diluted and full strength] used to remove and limit regrowth of *S. chartarum* on six varieties of GWB. The 13 cleaning products were manufactured by eight separate manufacturers; Reckitt and Colman (Slough, Berks, UK) produces Lysol, Lysol IC, and Lysol All Purpose Cleaner- Orange Breeze; The Clorox Company (Oakland CA) produces Bleach, Formula 409, Pine Sol and Tilex; S.C. Johnson and Son (Racine, WI) produces Fantastik Orange Action; Johnson Commercial Markets, Inc. (a subsidiary of S.C. Johnson and Son) produces Mildew Stain Remover with Bleach; Orange Glo International, Inc. (Greenwood Village, CO) produces Orange Glo Multipurpose Degreaser; Steris Corporation (Mentor, OH) produces SporKlenz; and Knight Marketing Corporation (Johnstown, NY) produces Spray Nine.

1.2 Wallboard sample description

Testing of the antimicrobial efficacy of these cleaning and disinfectant products was conducted to demonstrate the ability to remove and prevent the regrowth of *S. chartarum* growth on six varieties of GWB. Experiments were conducted at room temperature (21.1 °C or 70 °F) on six varieties of GWB surfaces cut into 7.6 x 7.6 cm (3.0 x 3.0 in) square coupons. The six types of GWB surfaces used were: 1. GWB (plain, no paint), 2. vinyl (100 percent vinyl) covered GWB, 3. GWB with vinyl coated wallpaper (removed before cleaning and replaced), 4. GWB with vinyl coated wallpaper (not removed before cleaning), 5. GWB with oil-based paint, and 6. GWB with acrylic (latex) paint.

All GWB products, cleaning products, paints, vinyl coated wallpaper, vinyl wall-covering, adhesives and other supplies used in these experiments were purchased from local distributors. At no time were manufacturers contacted for any reason regarding the research discussed in this paper.

1.3 Sample processing

Plain GWB coupons were cut and placed in self-sealing pouches, and steam sterilized by autoclaving. The coupons were then removed from the pouches and while in a biological safety hood (BSL2) allowed to cool and dry. The hood interior surfaces had previously been thoroughly wiped with alcohol and irradiated with a biostatic UV light as part of the routine preparation procedure. Then the GWB coupons were inoculated with 200 μ L (four equally separated pipetted amounts of 50 μ L each) of *Stachybotrys chartarum* spores, resulting in approximately 10^5 , or 100,000, colony forming units (CFUs) per test piece. After inoculation samples were placed in sterile petri dishes containing 4 mL of sterile water and then the dish was closed and placed into a static microbial test chamber maintained at 100 percent RH and room temperature (21.1⁰ C or 70.0⁰ F). The static microbial test chamber (SMTC) is constructed from acrylic sheeting (measures 32 x 39 x 51 cm) with shelves for samples and a saturated salt/water solution on the chamber bottom to control the equilibrium relative humidity. No air exchange through the chamber walls can occur, and measurable air movement within the chamber is not possible. The SMTC was tested using ASTM 6329-98, *Standard Guide for Developing Methodology for Evaluating the Ability of Indoor Materials to Support Microbial Growth Using Static Environmental Chambers* (2003). This method was developed as part of on-going indoor air biocontaminant research.

1.4 Coupon inoculation, paint and wallpaper application

For painted coupon surfaces, paint [primer (applied under wallpaper), oil-based or acrylic/latex] was applied using a clean, dry paintbrush for each type of paint or primer. Two types of paint were used: 1. oil-base semi-gloss enamel, Enterprise brand, Enterprise Paint Co., Wheeling, IL, a division of the Valspar Corporation, and 2. acrylic-latex wall paint, American Tradition brand, by Valspar Corporation. Samples were allowed to dry for 24 hours, then a second coat was applied. After an additional 24 hours for drying, the samples were placed into pouches and steam sterilized by autoclaving, and allowed to cool and dry on the counter. The painted GWB coupons were then removed from the pouches while in a biological safety hood (BSL2), allowed to cool and dry. The hood interior surfaces had previously been thoroughly wiped with alcohol and irradiated with a biostatic UV light as part of the routine preparation procedure. Then the

coupons were inoculated with 200 μL (four equally separated pipetted amounts of 50 μL each) of *S. chartarum* spores, resulting in approximately 10^5 , or 100,000, colony forming units (CFUs) per test piece. After inoculation samples were placed in sterile petri dishes containing 4 mL of sterile water and then the dish was closed and placed into a static chamber maintained at 100 percent RH and room temperature (21.1 $^{\circ}\text{C}$, or 70.0 $^{\circ}\text{F}$). The static chamber testing was based on ASTM Standard D6329-98.

When wallpaper (100 percent vinyl and vinyl coated wallpaper) was applied, GWB sample coupons were first painted as described above with primer as suggested by the manufacturer. The primer used was Colorplace brand, Interior Latex General Purpose Primer, marketed by WalMart Stores, Inc., Bentonville, AR. Each piece of wallpaper was first soaked in a petri dish of sterile water for one minute. The wallpaper was then removed from water drained and placed on the sample coupon. After applying the surface coating approximately 30 seconds was allowed to activate the glue before applying pressure to adhere it to the surface of the sample. The wallpapered samples were allowed to dry in the BSL2 hood as described above for 20 minutes prior to inoculation. Inoculation of the GWB wallpapered, and the GWB vinyl covered coupons surfaces was then conducted exactly as described above with 200 μL (four equally separated pipetted amounts of 50 μL each) of *S. chartarum* spores, resulting in approximately 10^5 , or 100,000, colony forming units (CFUs) per test piece.

1.5 Coupon cleaning

After inoculation, wetting, and static chamber storage, visual inspection of coupons continued for a period of one to two months, until they were found to have extensive *S. chartarum* growth, covering the coupon surface. Growth was estimated to be sufficient at varying periods between one to two months. The time required for sufficient growth was not an important consideration, but rather the primary consideration was the extent of growth over the coupon surface. When the coupon surface was extensively covered with growth over the majority of the surface with few bare spots remaining the coupons were removed from the chamber for cleaning. At which time the coupons of all six types of GWB surface treatments were cleaned with the products and by the manufacturers directions as listed in Table 2. After these heavily contaminated coupons were cleaned by the methods and products listed in Table 2, they were returned to sterile static chambers at 100 percent RH and room temperature (21.1 $^{\circ}\text{C}$, or 70.0 $^{\circ}\text{F}$) and stored for up to 6 months to allow for time to demonstrate potential regrowth.

When coupons of GWB 100 percent vinyl covering and one set of vinyl coated wallpaper were cleaned, the contaminated wallpaper was removed before cleaning. The GWB coupon surface was cleaned according to directions (nothing was done to the original coatings of primer paint), and the contaminated covering was discarded. After cleaning the samples of 100 percent vinyl and one set of vinyl coated wallpaper samples, new coverings were applied to the cleaned GWB and then the coupons were returned to the static chamber. The second set of vinyl coated wallpaper was cleaned without removing the wallpaper coating, allowed to dry and returned to the static chamber. Of the two sets of wallpaper, set 1. had the wallpaper removed, GWB surface cleaned, and clean (sterile) wallpaper replaced, while set 2. simply had the wallpaper surface cleaned but not replaced. The 100 percent vinyl coating was treated exactly as set 1. and after cleaning a new (sterile) covering of 100 percent vinyl was applied.

All cleaners that were diluted were prepared with sterile water. Sterile sponges were used to clean contaminated coupons and then were discarded. Recipes for dilution were prepared following directions listed in Table 2. The directions for each cleaner regarding application, wait time and rinsing were taken from the manufacturers product label and are listed in Table 2. A back and forth motion of approximately six times was used to clean the GWB square coupon surfaces [7.6 x 7.6 cm (3.0 x 3.0 in)]. If rinsing or wetting was required, a new sterile sponge dipped in sterile water was used for each sample. If time was required to let the product stand on the coupon surface than the coupon was kept in the BSL2 hood during the required length of time. For those instructions requiring spraying of the product onto the coupon surface, the original spray was used as stipulated in the instructions. If dry wiping was required, then a sterile sponge was used. A new pair of sterile gloves was used for each cleaner and each surface type.

1.6 Clean coupon processing

After cleaning, samples remained in the biosafety cabinet for a minimum of 30 minutes to dry before returning them to the 100 percent RH static chamber. When wallpaper was to be reapplied, coupons were first allowed to dry overnight in the biosafety cabinet, then the covering was applied following those procedures stated above. Coupons were then allowed to sit in the biosafety cabinet with the new wallpaper for one hour before returning to the 100 percent RH static chamber.

1.7 Coupon regrowth

Inspection for *S. chartarum* regrowth of the coupons within the static chambers extended up to six months.

Only those samples that exhibited heavy amounts of regrowth were stopped prior to six months. The estimation of regrowth was made by optical inspection of the coupon surfaces. The numerical ranking of mold growth followed was;

0 = No Growth,

1 = minimal growth,

2 = growth covering 1/3 of coupon,

3 = growth covering 1/2 of coupon,

4 = growth covering 3/4 of coupon,

5 = growth covering the majority of the coupon with few bare spots remaining.

Triplicate sample coupons were processed for each of the 14 cleaning products and six GWB surface types. Visual inspection for *S. chartarum* regrowth of the coupons within the static chambers occurred for six months or until it was judged to have extensive growth (a numerical ranking of 5).

2. Results

The observed regrowth results of the triplicate coupons were averaged for each test result of the 14 sets of experiments of cleaning products (13 separate cleaning products of which one product was tested in both diluted and full strength form). The 14 cleaning products and their manufacturer's directions were followed (see Table 2) to remove and limit regrowth of *S. chartarum* on six varieties of GWB (for the elaboration of cleaning techniques see the Materials and Methods section). The names of products listed in bold in Tables 1 and 2 were used as shortened versions of the commercial manufacturer's product name which are listed in Table 3. The averaged test results of these cleaning and disinfectant products are listed for each of the six varieties of GWB surfaces as following:

- 1) Plain GWB, no paint,
- 2) Vinyl (100 percent vinyl) covered GWB,
- 3) GWB with vinyl coated wallpaper removed before cleaning and replacing wallpaper,
- 4) GWB with vinyl coated wallpaper not removed before cleaning,
- 5) GWB with oil-based paint,
- 6) GWB with acrylic (latex) paint.

Growth rankings of 0 (meaning no observed growth) represented the best results and were placed toward the top of Table 3. Generally, cleaners with better overall results were listed higher on Table 3. Numerical results toward the bottom of Table 3 were the worst results recorded and represented significant mold regrowth.

3. Discussion

Results for the six types of GWB surfaces varied extensively. However, three cleaning products exhibited significantly better results than others. Lysol All-Purpose Cleaner-Orange Breeze (full strength) demonstrated results which ranked among the best in five of the six surfaces tested.

Both Borax and Orange Glo Multipurpose Degreaser demonstrated results which ranked among the best in four of the six surfaces tested. The mean growth ranking results for these three cleaning products for all six surfaces are listed in Table 3.

Lysol cleaner demonstrated results which ranked among the best in two of the six surfaces tested. Eight other cleaning products ranked among the best in at least one surface test, they were: Formula 409, Lysol IC, Pine Sol, Bleach, Spray Nine, Mildew Stain Remover with Bleach SporKlenz, Tilex, Fantastik Orange Action, and Lysol All-Purpose Cleaner-Orange Breeze (diluted).

The Table 3 results for vinyl (100 percent vinyl) covered GWB were comparatively lower than other varieties of GWB tested (11 lowest values for the 14 cleaner products tested). However, due to the constraints of visual identification of surface mold growth, and the thickness of this material compared to popular wall coverings, comparison of GWB materials was not meant to be evaluated. If GWB material evaluation was part of the objective, addition criterion would be necessary to allow for material inoculation and quantitative comparison of GWB. The only objective meant to be addressed by this research effort was the comparison of cleaning products. These products were compared within the context of six application of GWB.

Similarly to Krause, M. et. al. (2006), cleaning can be an option in some situations where removal may not be feasible. In cases where removal is being planned, cleaning as a temporary treatment option can reduce the extent of mold present and the possible spread or transport of mold in the indoor environment, as well as occupant exposure (Krause, M., et. al., 2006). Cleaning used in combination with preservation treatment such as painting with an antimicrobial paint can markedly retard the regrowth of mold such as *S. chartarum* (Price, D. L., and Ahearn, D. G., 1999).

4. Conclusion:

The best antimicrobial cleaner to choose is often dependent on the type of surface to be cleaned of *S. chartarum* contamination. For Plain GWB, no paint (see Table 3), the best cleaners were Borax, Lysol All-Purpose Cleaner-Orange Breeze (full strength), Orange Glo Multipurpose Degreaser, and Fantastik Orange Action.

For Vinyl (100 percent vinyl, removed, cleaned and replaced) covered GWB (see Table 3), the best cleaners were Formula 409, Lysol IC, Pine Sol, Borax, Lysol, Bleach, Spray Nine, Mildew Stain Remover with Bleach, Tilex, and Orange Glo Multipurpose Degreaser.

For GWB with vinyl coated wallpaper removed before cleaning and replaced (see Table 3), the best cleaners were Lysol All-Purpose Cleaner-Orange Breeze (full strength), and Orange Glo Multipurpose Degreaser.

For GWB with vinyl coated wallpaper not removed before cleaning (see Table 3), the best cleaners were Lysol All-Purpose Cleaner-Orange Breeze (full strength), and Orange Glo Multipurpose Degreaser, and Lysol All-Purpose Cleaner-Orange Breeze (diluted).

For GWB with oil-based paint (see Table 3), the best cleaners were Lysol All-Purpose Cleaner-Orange Breeze (full strength), Lysol and Borax.

For GWB with acrylic (latex) paint (See Table 3), the best cleaners were Borax, Lysol All-Purpose Cleaner-Orange Breeze (full strength) and SporKlenz.

Lysol All-Purpose Cleaner-Orange Breeze (full strength) demonstrated results which ranked among the best in five of the six surfaces tested. Both Borax and Orange Glo Multipurpose Degreaser demonstrated results which ranked among the best in four of the six surfaces tested.

Every product tested demonstrated to be among the best in at least one surface test.

5. Recommendations

These results are not meant to endorse the incomplete removal, or removal avoidance of mold contaminated building materials. However, it is recognized that complete removal may not always be possible, or a temporary cleaning may be desired until a permanent solution is planned. Consideration to these factors should be weighed in finding solutions to control mold growth and reduce or eliminate occupant exposure. Current recommendations of removal and replacement of porous building materials should be followed.

6. Outlook

It was not the intension of this discussion to endorse any product. Reporting on the performance of these products under the stated conditions was and remains the only purpose. The methodology employed in this paper can be used as a basis for further product testing protocol development. Comparative testing of all cleaning product efficacy can be helpful to consumer health and awareness.

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#	Cleaners Tested
1	Commercial Solutions Ultra Clorox Germicidal Bleach
2	Borax
3	Fantastik Orange Action
4	Formula 409 Multipurpose Cleaner
5	Lysol (concentrated)
6	Lysol All Purpose Cleaner Orange Breeze scent (full strength)
7	Lysol All Purpose Cleaner Orange Breeze scent (diluted)
8	Lysol IC - Brand Quaternary Disinfectant Cleaner
9	Johnson Wax Professional Mildew Stain Remover with Bleach
10	Orange Glo Multipurpose Degreaser
11	Pine Sol
12	SporKlenz
13	Spray Nine Multi-Purpose Cleaner & Disinfectant
14	Tilex

Table 1, Cleaners Tested

Cleaning Product	Directions For Use	Concentration
Lysol (concentrated)	To disinfect/deodorize hard, non-porous surfaces, remove heavy soil first, then add 1.3 oz to one gallon water then apply with a sponge or mop wetting all surfaces thoroughly. Let stand 10 minutes, then wipe away excess.	189 mL H ₂ O 1.89 mL Lysol
Lysol All Purpose Cleaner Orange Breeze scent	For a cleaner, fresher household, dilute 2 oz. with a gallon of warm water. Good for everyday cleaning throughout the house. For your toughest household messes., use full strength and rinse thoroughly.	full strength
Lysol All Purpose Cleaner Orange Breeze scent	For a cleaner, fresher household, dilute 2 oz. with a gallon of warm water. Good for everyday cleaning throughout the house. For your toughest household messes., use full strength and rinse thoroughly.	250 mL H ₂ O 3.75 mL Lysol Orange Breeze
Lysol IC - Brand Quaternary Disinfectant Cleaner	Remove heavy soil deposits from surfaces, then thoroughly wet them with a solution of 1/2 oz of the concentrate per gallon of water. The solution can be applied with a cloth, mop, sponge or coarse spray or soaking. Let solution remain on surface for a minimum of 10 minutes. Allow to air dry.	378.5 mL H ₂ O 1.48 mL Lysol I.C.
Spray Nine Multi-Purpose Cleaner & Disinfectant	1. Spray on soiled surface. 2. Wipe immediately with a clean, damp sponge or cloth. 3. Repeat application making sure to wet all surfaces thoroughly. 4. Allow to stand for 3 minutes when treating for fungus. 5. Wipe off with a clean, damp sponge or cloth then rinse thoroughly.	full strength
Johnson Wax Professional Mildew Stain Remover with Bleach	Spray using full strokes, 6-8" from surface. Wait until stains disappear. Wipe with sponge. Rinse promptly.	full strength
Commercial Solutions Ultra Clorox Germicidal Bleach	Prewash surface, mop or wipe with bleach solution. Allow solution to contact surface for at least 2 minutes. Rinse well and air dry. Dilute 2/3 cup bleach to 1 gallon water.	189 mL H ₂ O 7.89 mL bleach
SporKlenz	Remove any obvious debris or organic material from the surface to be sterilized. Dilute Spor-Klenz concentrate 100x (1 part Spor-Klenz to 99 parts purified water). Spray onto surfaces using a plastic spray bottle. Allow to remain on surface for 10 minutes. Let air dry or rinse with purified water.	175 mL H ₂ O 1.75 mL SporKlenz
Borax	Sprinkle borax into water and wipe with damp sponge.	473 mL of warm water 1 Tablespoon Borax full strength
Pine Sol	For general disinfecting: Apply Original Pine-Sol Brand cleaner with a sponge or cloth full strength. Wet surfaces, let stand 5 minutes, then remove excess. For highly soiled areas, clean excess dirt first.	

Tilex	Spray surface until thoroughly wet, let stand 5 minutes and rinse. Do not use on wood or painted surfaces. Avoid contact with aluminum, clothes, fabric, carpet or paper surfaces as they will discolor.	full strength
Fantastik	Spray 6-8 inches from surface.	full strength
Orange Action	After spraying, wipe with a dry paper towel or cloth.	
Orange Glo	Spray on soiled area and wipe clean. Rinse if necessary. For baked-on grease or thick soap film, wait several minutes before wiping.	full strength
Multipurpose Degreaser		
Formula 409	Spray 6-8 inches from surface. General cleaning: Spray product straight onto soils and wipe clean with a dry paper towel or lint free cloth. Repeat for heavily soiled areas. Not recommended for use on soft vinyl, varnishes or aluminum.	full strength
Multipurpose Cleaner		

Table 2 Cleaning products tested for removing *Stachybotrys chartarium* growth

Mean growth ranked 0 to 5 for each surface type	A	B	C	D	E	F
Lysol All-Purpose Cleaner- Orange Breeze (full strength)	0.0	3.7	0.0	0.0	0.0	0.0
Borax	0.0	0.0	1.0	2.0	0.0	0.0
Orange Glo Multipurpose Degreaser	0.0	0.0	0.0	0.0	1.0	4.0
Fantastik Orange Action	0.0	3.3	2.3	0.7	0.3	2.3
Lysol IC - Brand Quaternary Disinfectant Cleaner	0.7	0.0	1.0	1.0	3.0	5.0
Formula 409 Multipurpose Cleaner	1.3	0.0	2.0	1.0	1.0	4.0
Lysol (concentrated)	3.0	0.0	1.0	3.0	0.0	1.7
Tilex	2.0	0.0	1.7	2.7	0.7	2.0
Spray Nine Multi-Purpose Cleaner & Disinfectant	2.7	0.0	1.0	3.0	1.0	1.7
SporKlenz	2.3	0.7	0.7	2.0	2.0	0.0
Pine Sol	2.0	0.0	0.3	2.0	0.7	0.7
Commercial Solutions Ultra Clorox Germicidal Bleach	5.0	0.0	1.0	3.3	1.7	0.7
Johnson Wax Professional Mildew Stain Remover with Bleach	3.7	0.0	1.0	2.3	1.7	1.3
Lysol All Purpose Cleaner Orange Breeze scent (diluted)	4.0	4.3	5.0	0.0	3.0	3.3

Table 3 Comparison *Stachybotrys chartarium* growth for cleaners on six GWB surface types

- A. Plain GWB, no paint,
- B. Vinyl (100 percent vinyl) covered GWB,
- C. GWB with vinyl coated wallpaper removed before cleaning and replacement,
- D. GWB with vinyl coated wallpaper not removed before cleaning,
- E. GWB with oil-based paint,
- F. GWB with acrylic (latex) paint.