Cleaning Effectiveness Demonstration In A Carpet School

Final Report

Prepared by:
Karin Foarde
Deborah Franke
RTI
Research Triangle Park, NC 27709

and

Michael A. Berry
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599

Prepared for:
Ken Mcintosh
Carpet and Rug Institute
Dalton, GA 30722

RTI Project number: 07755.001.002
November 2002

RTI INTERNATIONAL

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INTRODUCTION

A study completed in 1994, Cleaning for Improved Indoor Air Quality: An Initial Assessment of Effectiveness, evaluated how cleaning and maintenance could help control particles, chemicals, and biocontaminants in a building in North Carolina (Franke et al., 1997). The study building was a four-story, mixed-use building (offices, laboratories, and a daycare center) that had no evident problems and no history of complaints. This study was important because it was one of the first to look for biocontaminants in a building without any known problems. Generally, studies of biocontaminants evaluate remediation, not prevention, of problems. However, even in a nonproblem building, there are locations where biocontaminants can accumulate and therefore have the potential to become a problem. Some of these locations are not cleanable, while others are. Cleanable locations include many of the building furnishings and materials as well as surfaces within the building.

The objective of that study was to assess the effectiveness of a standardized, routine cleaning program to better control biocontaminant sources. The building was monitored once a month looking for long-term effects and seasonal differences. The goal was to collect information on normal building ecology and to develop a study approach to assess standard cleaning guidelines. The study was a collaborative effort between the Research Triangle Institute, the U.S. Environmental Protection Agency, the University of North Carolina at Chapel Hill, a building service contractor, and the commercial cleaning and carpet industries and their suppliers.

The study started with a four-month precleaning baseline assessment followed by a thorough building cleaning to eliminate potential pollutant sources. The cleaning included professional deep cleaning, training of housekeeping staff, and provision of new equipment. The cleaning was followed by a seven-month postcleaning characterization. The results showed that an organized cleaning program based on environmental management principles can contribute to measurably better control of biocontaminant sources in a building.

Two recommendations came out of that study. One was to compare biocontaminant levels in carpeted and noncarpeted environments. This study was recently completed (Foarde and Berry, 2002). The second was to evaluate the long-term impact of a cost-effective carpet cleaning program, which was the objective of the project described in this report.

As in the 1994 study, the focus of this 2001-2002 school study was to evaluate the contribution of cleaning and maintenance to source management of biocontaminants in a nonproblem, noncomplaint, carpeted building. Because children spend so many hours in school, the school environment is particularly important, and the prevention of biocontamination source development has not been studied in schools. The objective was to implement a cost-effective, standardized, routine carpet cleaning program in a school, and to assess how much it helped control biocontaminant accumulation in carpets.

The custodial staff was asked to participate. As part of the study, the school was provided with extraction machines, vacuum cleaners, and a cost-effective carpet cleaning program and schedule. Training was provided on the use of the equipment and the carpet cleaning program. The overall goal was to re-

duce the existing workload required to maintain the carpet, therefore, any increase in responsibilities or workload was not considered cost effective and not included in the cleaning program. All the carpet-cleaning equipment and vacuum cleaners became the property of the school at the end of the study.

For the purpose of this environmentally-based study, cleaning was defined as the process of locating, identifying, containing, removing, and properly disposing of an unwanted substance from a surface or environment. Cleaning machines and vacuum cleaners were selected that had been previously tested to achieve maximum extraction of carpet soils and contaminants and minimum residue. For example, CRI Green Label Vacuums were used in the study, along with lab- and field-tested carpet cleaning chemicals and high flow carpet cleaning machines.

Air and dust samples were collect from the school. The air samples were analyzed for culturable fungi, total airborne spores, allergens (dust mite, cockroach, and cat), airborne dust mass, endotoxins, and β-1,3 glucans. The dust samples were analyzed for culturable fungi, allergens (dust mite, cockroach, and cat), endotoxins, and β-1,3 glucans.

The contaminants to be sampled were carefully selected to provide a broad range of information as well as some internal checks and balances. This was especially important because the results from a single contaminant might be misleading. Using multiple markers and different methods allows us to state our conclusions much more strongly. The total spores, culturable fungi, and β-1,3 glucans are different parameters, but all are designed to quantify fungal contamination levels. The measurement of total spores quantifies the total number of spores without regard to culturability or viability. This was important because, generally, only 1 to 10 percent of the total spores would be expected to be culturable. β-1,3 glucans were selected as a biochemical marker for fungal contamination. One of the primary sources of β-1,3 glucans in the environment is fungus, so a reasonable correlation with total spores and culturable fungi would be expected.

Dust mite, cat, and cockroach antigen were selected because they are commonly associated with allergy and asthma. While dust mites and cockroaches would be expected in schools, cats would not. Generally, cat antigen is thought to be brought into schools on the clothing of cat owners. Endotoxin was selected primarily because inhalation of endotoxins has been shown to increase nonspecific bronchial reactivity in asthmatics and can be used as a biochemical marker for gram-negative bacteria.

The airborne dust mass samples that were collected were $PM_{2.5}$, defined as particulate matter with aerodynamic diameters less than 2.5 μm. This size fraction is respirable. In addition, dust mite, cockroach, and cat allergens and endotoxins and β-1,3 glucans were quantified in the airborne $PM_{2.5}$ airborne dust sample.

DESCRIPTION OF PARTICIPANT SCHOOL

The school was a noncomplaint, nonproblem, carpeted elementary school. The school was situated in a rural location in North Carolina. It was first occupied in 1996. Comfort air conditioning was accomplished with zoned air handling units (AHUs). Zones included multiple classrooms and auxiliary rooms. Oil-fired boilers provided steam to the AHU coils for the heating season, and packaged chillers provided

chilled water to coils during the cooling season. Humidity was not controlled through reheat. The boilers and chillers were operated together only for a few weeks during the spring and fall when both heating and cooling might be required within a short period. The system appeared well-maintained. Four air filters were used in each AHU. The filters were basic efficiency fiberglass panel filters.

The classroom floor area was two-thirds carpet and one-third tile. The halls, kitchen, cafeteria, and art room were tiled; the music room, general purpose room, administrative areas, and media center were carpeted. In total, approximately 70 to 75 percent of the floor was carpeted. In our initial survey of schools, we determined that this percentage would be typical of a carpeted school.

The school system has a standard operating procedure for the cleaning and maintenance of all of the schools in the system. As best we could determine, it had been followed in the past.

The school management was totally supportive of the research effort. The principal of the school was enthusiastic about the project and delighted to become the owner of the carpet cleaning equipment and vacuum cleaners at the end of the study. She was devoted to creating a school environment that was completely focused on what was best for the children that attended the school. The school staff was also absolutely committed to the children. The custodial staff consisted of the head custodian, two full time custodians, and a third half-time custodian. The custodial supervisor for the school system and the director of maintenance were also supportive of the effort. The principal encouraged respect and support for the custodial staff. During each school year there were clean-up days where all the classes picked-up their rooms and the outdoor areas.

CLEANING PROGRAM

The cleaning program was developed by Dr. Michael Berry of the University of North Carolina at Chapel Hill, Mr. Buzz Cohen of Complete Cleaning Contractors in Lodi, OH, and Mr. John Downey of Steamin' Demon in Granville, OH. The training program was developed and implemented by Mr. Cohen. The text below describing the training was originally written by Mr. Cohen and has been adapted for this report.

Training

Training was conducted as a three-step process: tell 'em, show 'em, let 'em do it. We used two rooms, side-by-side, to conduct the training. The first room was as dirty as possible. This was the tell 'em and show 'em room. The second room was for them to use for the final let-'em-do-it part of the training.

A. Vacuuming- Focus was on 1) learning the operation of new vacuums, 2) ensuring they were in proper working order, and 3) following a cleaning regimen that included a monthly scheduled, thorough, wall-to-wall vacuuming of each room in addition to daily vacuuming of heavy traffic areas.

B. Spotting- Focus was on the five most common spotting situations encountered. (We asked the head custodian for a list. We expected it to include: vomit/body fluids, water damage, rust, Coke

and/or coffee.) Each cleaning-team member received laminated sheets covering spot-removal techniques for those five spots.

C. Cleaning- Focus was on the nine steps of cleaning, as outlined by the IICRC for hot water extraction cleaning, using a high-flow, high-extraction system (IICRC, 2002):
1. Preinspect
2. Prevacuum
3. Prespot
4. Precondition
5. Agitate
6. Dwell time
7. Extraction
8. Grooming
9. Drying

As with spotting, each cleaning-team member received a laminated sheet covering the cleaning system.

Cleaning Plan/Protocol

Other than the improvements in training, the use of effective cleaning equipment, and in the cleaning systems employed, we had a couple suggestions that if incorporated into the cleaning routine we believed would result in tangible improvements in the condition of the carpet.

A. Vacuuming: Based on the information provided by the head custodian (vacuuming rate of 10,000 square feet per hour), the system of daily vacuuming prior to implementation of this plan was by no means thorough or complete; instead, we believed it was primarily debris collection and traffic area cleaning. We believed it was important to make sure that each room was properly and thoroughly vacuumed, wall to wall, on a monthly basis. Accordingly, we built that into the protocol and provided staff with training and a color-coded plan to accomplish it.

B. Extraction cleaning: In addition to the two cleanings planned, we believed a tangible benefit would be derived from monthly extraction cleaning of the school office entry area and hallway, and two additional cleanings of the traffic areas of the media center. It was our understanding that, unlike the rest of the school, both of these areas are open year round and both receive substantially higher levels of outside traffic than the rest of the school. Based on the increased productivity that was realized when the new extraction cleaning system was employed, this was achieved without any increase in the overall time required for extraction cleaning.

Equipment and Supplies

Following is a list of cleaning equipment and supplies:

4- Windsor Versamatic, model VS18 (CRI Green Label tested)
3- Steamin Demon II High-Flow xxtractors
3- Extra 50 ft. supply and drain hose assemblies for extractors
3- Grandi-Groomers

6- 21 inch Lakewood drying fans
4 gallons- Steamin Demon Prespray
4 gallons- Steamin Demon Defoamer
6 quarts plus 4 gallons- Perky spotter
6 quarts- Bridgepoint T-Rust spotter
6 quarts- Bridgepoint Solvent Spotter
6- Core T-Bone Spatulas (or Bridgepoint Gum-Getters)

MATERIALS AND METHODS

The cleaning assessment focused on biocontaminants. Air and floor samples were collected. The air samples were analyzed for culturable fungi, total airborne spores, airborne dust mass ($PM_{2.5}$), allergens (dust mite, cockroach, and cat), endotoxins, and β-1,3 glucans. The dust samples were analyzed for culturable fungi, allergens (dust mite, cockroach, and cat), endotoxins, and β-1,3 glucans. The test matrix is shown in Table 1.

Table 1. Test Matrix – Number of Samples

POLLUTANT	YEAR #1			YEAR #2		
	INDOOR		OUT-DOOR	INDOOR		OUT-DOOR
	AIR	DUST	AIR	AIR	DUST	AIR
Culturable Fungi (xerophillic)	25	25	15	20	20	8
Total airborne spores	20	ND	20	20	ND	8
Allergens (dust mites, cockroach, cat)	50	30	20	30	40	8
Airborne dust mass	20	ND	20	20	ND	8
Endotoxins/β-1,3 glucans	25	15	25	20	40	8
Total	140	70	90	110	100	40

ND = Not determined.

One of our primary goals was to collect a sufficient number of samples to perform statistical analyses on each parameter. Therefore, between three and five replicate samples (depending upon the pollutant) were collected and analyzed each sampling trip.

Collection of Samples

The school was sampled six times throughout the school year for the precleaning portion of the study, May (the end of school), September (the beginning of school), November, January, March and May again. Post-cleaning sampling took place in July, August (the beginning of school) October, December, January, March and May for a total of seven trips. The extraction cleanings took place before the July sampling trip, and between the December and January sampling trips.

All samples were collected during the school day while the schools were in session. No attempt was made to limit normal student activity. Air samples were collected using a variety of samplers and protocols depending upon the pollutant being measured. The total airborne spores were collected using Air-O-Cells (Zefon Analytical Accessories, Fl). The airborne dust mass ($PM_{2.5}$) was collected on 2 μm pore-size 47 mm PTFE filters using URG's Fine Particle Sampler. The same filters were analyzed for the three allergens, endotoxins, and β-1,3 glucans.

The culturable fungi were sampled using a Mattson-Garvin slit-to-agar impactor. The Mattson-Garvin draws air at 28.3 L/min through a metal inlet with a 0.006-inch slit, allowing the impaction of an extensive size range of airborne organisms on the surface of a rotating agar plate.

Air-O-Cells are preloaded cassettes containing a glass slide coated with a sticky impaction medium. The base of the cassette is connected to a pump using flexible tubing and air is drawn onto the impaction surface at 28.3 L/min through a slit in the top of the cassette.

The URG Fine Particle Sampler consists of an air pump that maintains constant flow throughout sampling. A 47 mm PTFE filter is loaded into a filter pack containing various stages separated by Teflon-coated mesh screens. The filter is placed on the top stage of the filter pack. Above the filter, a 2.5 μm cut cyclone is screwed into the filter pack. The cyclone is also coated with Teflon to prevent particle loss within the inlet. The entire apparatus is connected with flexible tubing to the pump, and samples are collected at 16.7 L/min for 2 hours each.

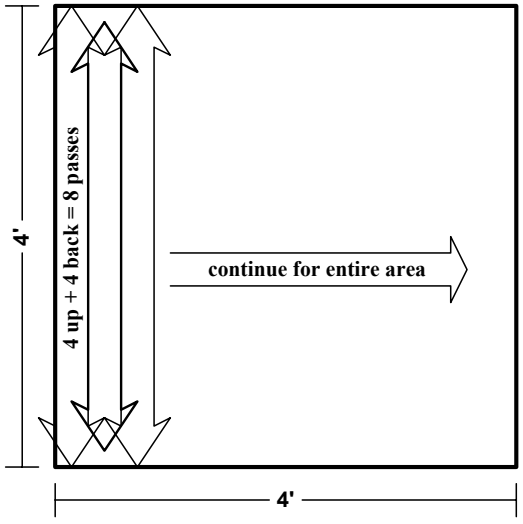

Figure 1. Vacuum pattern used for the HVS3 floor dust sampling

All dust samples were collected with the High Volume Surface Sampler or HVS3. The HVS3 was developed through the EPA for the collection of dust from carpets and bare floors. The dust can be analyzed for lead, pesticides, or other chemical compounds and elements. The American Society for Testing and Materials (ASTM) standard practice D5438 describes the protocols, and the applicability of the HVS3 to a variety of carpeted and bare floor surfaces (ASTM, 1994). The HVS3 has been tested for level loop and plush pile carpets and bare wood floors. RTI developed a procedure for using the HVS3 to collect dusts for microbiological assays (Leese et al., 1993).

The HVS3 uses a 1-horsepower vacuum motor and a specifically designed nozzle and cyclone trap. The unit has

magnehelic gauges that are used to manually set the flow rate and pressure drop across the nozzle at the monitored surface. The cyclone effectively collects 99 percent of the dust mass lifted by the vacuum (Roberts et al., 1991).

Upon arrival at the field site, five separate carpeted or smooth flooring areas were designated for sampling. Using a steel template measuring 4'×4', squares were laid out on the floor, and marked with masking tape. Each square was sampled following the sampling pattern shown in Figure 1.

The sampling pattern consisted of first vacuuming following upward and downward strokes for eight consecutive passes. The operator then moved the sampler to the right of the completed strokes and repeated the series. The series was repeated until the entire sampling area was covered. The sample bottles for the HVS3 were preweighed in the laboratory prior to leaving for the field site. After sampling, the bottles were brought back to RTI, postweighed, and the net increase in weight recorded. On each trip samples were collected from five indoor locations.

Sample Analyses

The culturable fungi were grown on DG18 for the xerophillic organisms. The predominant organisms were enumerated and identified to at least the genus level.

Airborne dust mass was quantified by weighing PTFE air filters. The filters were equilibrated at 30 to 35 percent relative humidity in the weighing chamber for at least 16 hours. The filters were weighed on a seven-place balance following a standardized weighing program which promotes consistency throughout the weighing process. Pre- and postweighing procedures were the same. The operator who performed the preweighing, also postweighed the filters. The net weight change was recorded. After weighing, the filters were extracted for the antigen, endotoxin, and β-1,3 glucan analyses.

The allergen (dust mite, cat, and cockroach) contents were assayed using a modification of the Food and Drug Administration procedure (FDA, 1994) for the Enzyme Linked ImmunoSorbent Assay (ELISA) inhibition (competition). This assay is a polyclonal assay (detects multiple antigens) designed to be specific for the test antigens (i.e., *Der f*). We selected this assay over the monoclonal (detects one specific antigen) because, like the monoclonal, it is specific for the test antigens but inclusive of more antigens than the monoclonal and results in a lower minimum detection limit. The assay determines the relative potency of the antigen in the test sample compared to a standard antigen preparation.

Endotoxins and β-1,3 glucans were quantified using endotoxin-specific and β-1,3 glucan-specific Limulus amebocyte lysate assays, respectively.

Total airborne spores were quantified by analysis of the Air-O-Cells. Each Air-O-Cell cassette was opened, and the internal glass slide containing the impaction medium was removed. The slide was placed onto a microscope slide and stained with lacto-glycerol. Total airborne spores were counted microscopically at 600X magnification.

Statistical Analyses

The primary purpose of the statistical analysis was to determine whether the differences in the levels of the various contaminants quantified pre- and post-cleaning were statistically significant. The differences

were calculated in a SAS data step, and the t-test was performed by proc univariate (in SAS[1]).

The analysis of any parameter group (e.g., surface glucan loading, or surface endotoxin concentration, or fungi indoor air, etc.) was accomplished by calculating the mean finding (that is, LOGFINDn) for each year and location, calculating the difference between the Year2 finding and the Year1 finding (Diff=Year2-Year1) at each location, and testing whether the mean difference across the three locations was less than zero. This is a one-tailed t-test. If the t-test indicated that the difference was significantly less than zero, one might claim that this result was due to the special cleaning.

RESULTS

The results of the carpet surface dust analyses are shown in Tables 2 and 3. The dust loading data found in Table 2 are expressed in terms of area (square meter) of floor. The concentration data in Table 3 are expressed per gram of dust. The data are presented as the geometric mean (GM) and geometric standard deviation (GSD) over the full year of sampling. The GSD is a number greater than 1 that describes the breadth of the distribution of values when the geometric mean is used. The GSD is the ratio of the 84th percentile of the distribution to the mean of the distribution. That is, 84 percent of the distribution lies within a value equal to GSD times the mean value. A GSD of 1.4 indicates a narrow range of values in the distribution; the 84th percentile is at only 1.4 times the mean value. A GSD of 6 represents a broad range of values in the distribution: 6 times the mean value will encompass only 84 percent of all the values.

As discussed above, a statistical analysis was performed to assist in the interpretation of the data. The conventional level of statistical significance that is commonly used is $p < .05$. In other words, a 95

Table 2. Summary of Floor Dust Loading Analyses (Contaminant Expressed Per Floor Area)

CONTAMINANT	TREATMENT	FLOORING GM (GSD)
Dust Mass (µg dust/m^2)	Pre-Clean	**790 (3.3)**
	Post-Clean	**220 (3.1)**
Endotoxin (EU/m^2)	Pre-Clean	**34,000 (4.4)**
	Post-Clean	**3,060 (4.1)**
β- (1,3) Glucan (ng/m^2)	Pre-Clean	**973,000 (6.3)**
	Post-Clean	**192,000 (5.3)**
Dust Mite Antigen (ng/m^2)	Pre-Clean	5,300 (5.2)
	Post-Clean	4,000 (5.2)
Cat Antigen (ng/m^2)	Pre-Clean	**4,700 (3.3)**
	Post-Clean	**2,100 (4.0)**
Cockroach Antigen (ng/m^2)	Pre-Clean	**3,600 (5.8)**
	Post-Clean	**1,500 (5.1)**
Culturable Fungi (CFU/ m^2)	Pre-Clean	2,900 (5.4)
	Post-Clean	5,600 (3.8)

Bolded text = statistically significantly different ($p < 0.05$)

[1]SAS is the registered trademark of SAS Institute, Inc., Cary, NC.

percent likelihood that the difference in the means is not due to chance is required to establish significance. Those results that are statistically significant are bolded in the tables.

As seen in Table 2, the differences in the carpet loading data between year 1 (pre-clean) and year 2 (postclean) were statistically significant for all of the tested parameters, except dust mite antigen and culturable fungi. The largest decrease was in the endotoxin levels.

The analysis of the concentration data (Table 3) show no statistically significant differences in the concentration of any of the contaminants in the dust between the pre- and post-cleaning, except for endotoxin ($p<.01$) and dust mite antigen ($p<.05$). While endotoxin levels decreased, the amount of dust mite antigen increased. The increase in dust mite antigen concentration combined with the lack of a decrease in dust loading suggest that there may be an active dust mite problem in the school. While cleaning may be helping to keep the problem in check, it is not eliminating the source, the dust mites themselves. The endotoxin decrease is very interesting, the very large statistically significant decrease in loading, combined with the decrease in concentration in the dust, suggest that the cleaning, possibly the

Table 3. Summary of Floor Dust Concentration Analyses (Contaminant Expressed per Gram of Floor)

TREATMENT	CONTAMINANT					
	Mite Antigen (ng/g) GM (GSD)	Cat Antigen (ng/g) GM (GSD)	Cockroach Antigen (ng/g) GM (GSD)	Endotoxin (EU/g) GM (GSD)	β-1,3 Glucans (ng/g) GM (GSD)	Fungi (CFU/g) GM (GSD)
Pre-Clean	**6,800 (3.0)**	6,000 (1.9)	4,700 (2.8)	**43,000 (2.5)**	1,250,000 (2.5)	5,000 (2.5)
Post-Clean	**12,000 (2.3)**	6,400 (2.0)	4,600 (2.7)	**14,000 (2.8)**	970,000 (2.4)	4,800 (3.2)

Bolded text = statistically significant difference ($p < .05$).

extraction process, is removing endotoxin beyond the dust removal of the vacuuming.

The data are presented graphically in the plots found in Appendix A. Each of the contaminants are plotted separately by both surface loading and surface concentration. The data are plotted by building location. A line representing the geometric means are shown for year 1 and year 2.

The airborne data shown in Table 4 are separated into outdoor and indoor measurements and expressed in terms of the volume (cubic meter) of air. For the contaminants measured in the outdoor air, there was no overall statistically significant difference between schools for any of the parameters except for cat antigen. The level of cat antigen was higher the second year than the first year. Generally, cat antigen is thought to originate primarily from indoor sources; however, it is possible that there was a cat in the neighborhood the second year and we were unaware of it. Overall, the outdoor concentrations were similar for the two years.

As expected, the outdoor spores and culturable fungi CFUs) exceed the indoors, indicating a functioning air filtration system in the HVAC. In a nonproblem, noncomplaint school, the primary source of spores and culturable fungi is the outdoor air.

Table 4. Summary of Airborne Data.

CONTAMINANT	YEAR	OUTDOOR GM (GSD)	INDOOR GM (GSD)
Endotoxin (EU/m^3)	1	0.2 (1.9)	**0.2 (2.3)**
	2	0.1 (1.5)	**0.1 (1.4)**
β- (1,3) Glucan (ng/m^3)	1	0.2 (2.3)	**0.2 (1.4)**
	2	0.2 (2.7)	**0.1 (1.6)**
$PM_{2.5}$ Dust Mass ($\mu g\ dust/m^3$)	1	10.1 (1.9)	8.1(1.9)
	2	13.3 (2.0)	10.4 (1.9)
Dust Mite Antigen (ng/m^3)	1	21.9 (2.0)	39 (3)
	2	24.2 (1.9)	32 (3)
Cat Antigen (ng/m^3)	1	**21.6 (2.0)**	53 (5)
	2	**92.4 (4.3)**	83 (5)
Cockroach Antigen (ng/m^3)	1	40.3 (2.5)	**100 (4)**
	2	43.8 (2.6)	**34 (1.9)**
Culturable Fungi (CFU/m^3)	1	600 (3.1)	50 (2.4)
	2	400 (2.9)	70 (2.4)
Total Spores ($spores/m^3$)	1	10,800 (4.0)	**1,200 (2.8)**
	2	7,200 (4.5)	**690(2.3)**

Bolded text = statistically significantly different ($p < 0.05$)

For the indoor air concentrations, there were significant differences between the two years for spores ($p < .05$) and β-1,3 glucan ($p < .01$) and for cockroach antigen ($p < .01$) and endotoxin ($p < .01$). In all cases, the second year or post cleaning values were lower than the pre-cleaned values.

DISCUSSION

To better understand the results, the percentage reductions (decrease in year 2 compared to year 1) after implementing the cleaning program were calculated. Table 5 summarizes the reductions. The first column lists the contaminant. The second and third columns show the reductions in floor dust contaminant by loading and by concentration, respectively. The final column shows the percent reduction for each contaminant in the air.

To fully evaluate the impact of this particular cleaning program, it is important to consider each contaminant separately. They have different sources, as well as physical and chemical characteristics. For example, dust mites live in carpets and other fleecy materials. The source of the antigen is primarily the fecal pellet, which dries up and becomes friable. While some of the particles are relatively readily removed, in other studies we have seen that some of the antigen is sticky and difficult to remove (unpublished data). Cat antigen is a component of cat dander. In a school environment, it is usually brought in on the students and teachers. Endotoxin is a constituent of the cell walls of gram negative bacteria. In carpet dust, most of the endotoxin probably originates from the soil or dirt tracked into the school.

Table 5. Percent Reductions in Floor Dust Loading and Concentration and Airborne Levels

CONTAMINANT	Floor Dust		% Reduction in Airborne Indoor Levels
	% Reduction in Loading	% Reduction in Concentration	
Dust	**59**	Not Applicable	No Change
Endotoxin	**86**	**67**	**56**
β- (1,3) Glucan	**67**	22	**48**
Dust Mite Antigen	25	**Increase**	No Change
Cat Antigen	**56**	No Change	No Change
Cockroach Antigen	**59**	1.3	**66**
Culturable Fungi	Increase	4	No Change

Bolded text = statistically significantly different ($p < 0.05$)

Both the surface loading and concentration of each contaminant need to be considered in order to understand the impact on the air concentration. As can be seen from the table, the amount of dust we were able to collect with the HVS3 decreased 59% after implementing the cleaning program, but there was no change in the airborne levels of dust. This suggests that the main source of $PM_{2.5}$ dust in the school was not the carpet. The endotoxin results are very different. The cleaning program resulted in an 86% reduction in loading and a 67% reduction in concentration in the dust. This suggests that the cleaning program (possibly the extraction) resulted in a reduction beyond that of dust removal. Similar results were seen for the β- (1,3) glucan. While the decrease in concentration was not statistically significant, the decrease in airborne level was. The reduction in cat antigen loading in the floor dust was statistically significant; however, the concentration data showed an increase.

The pattern that emerges is that a reduction in airborne contamination attributable to carpet cleaning is a function of both the source/nature of the contaminant and the effectiveness of the cleaning process.

CONCLUSIONS

The objective of this study was to evaluate the long-term impact of a cost-effective carpet cleaning program in a school. The results showed that there were significant decreases in the pre- and post-cleaning levels of airborne of endotoxins (56%), β-1,3 glucan (48%), and cockroach antigen (66%). There was no difference in the airborne levels for the $PM_{2.5}$ dust mass, dust mite and cat allergens, and culturable

fungi. All of the outdoor air levels remained the same over the two years, except for the cat antigen level that increased.

To understand how the airborne levels are affected by a surface cleaning program it is necessary to consider the impact of the cleaning on both surface contaminant loading and concentration. The cleaning program resulted in statistically significant reductions in the surface loading for all of the contaminants except dust mite antigen and culturable fungi. Floor contaminant concentration significantly decreased for endotoxin, but significantly increased for dust mite antigen.

Key to a successful cleaning program is effective extraction equipment, a system and schedule for cleaning, and the positive and proactive attitude of the custodial staff and leadership of the school and the school system. This school was well maintained before the study started. The cleaning program introduced by the study simply incorporated and reinforced that positive attitude. The custodial staff was conscientious and aware of their importance of their work in achieving a healthy school environment. Support from the school administration, effective equipment, training in the basics of cleaning science, and an achievable, cost effective cleaning program were essential to the positive outcome of this study.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the technical assistance of Tricia Webber of RTI for coordinating all of the field sampling and lab analyses. We would also like to express our appreciation to Michael Herman, Kelley Fitzgerald and Elizabeth Rodes of RTI for their excellent technical performance in the lab and the field.

Ms. Alice Cobb, the principal of the school, was an enthusiastic supporter of the study. She is devoted to creating a school environment that is completely focused on what is best for the children attending the school. The entire school staff was absolutely committed to the children. A special thanks to Mr. Lawrence Frazier, the head custodian, and the custodial staff Gladolia McGlotten, Edison Ray, James Williams and Ramon Torres for committing themselves to the study. Without them the project would not have been possible.

We appreciate the support of CRI in funding the study, and of Cary Mitchell and Shaw Industries for being on site throughout the study and assisting us far and above what they had committed to do. Their assistance was deeply appreciated. Finally, we also thank Mr. Buzz Cohen of Complete Cleaning Contractors in Lodi, OH, and Mr. John Downey of Steamin' Demon in Granville, OH. Their work with the custodial staff of the school was indispensable.

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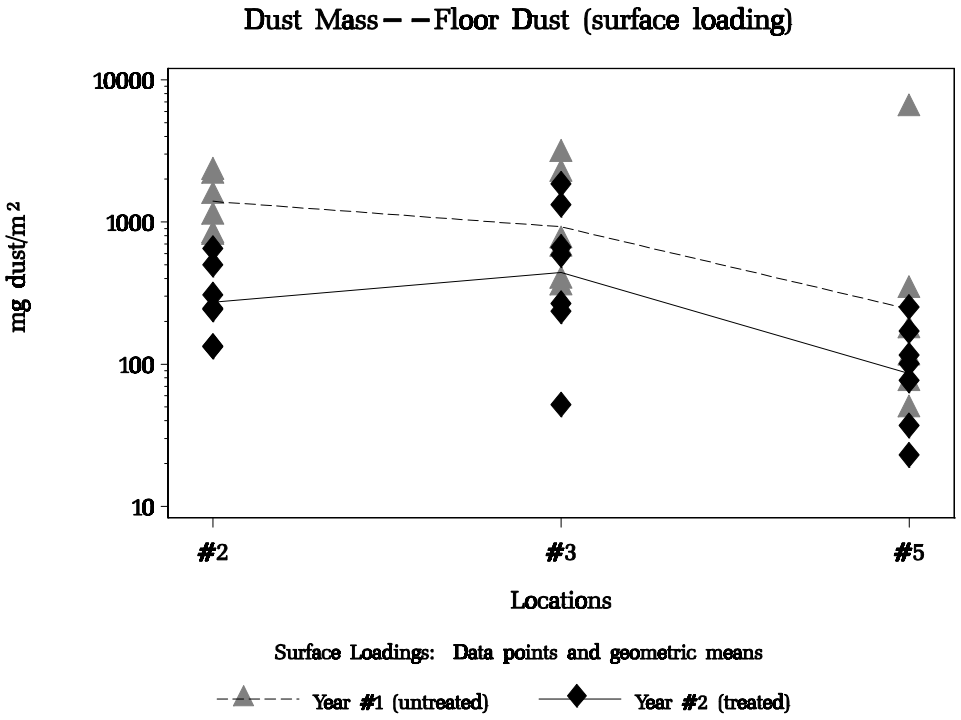
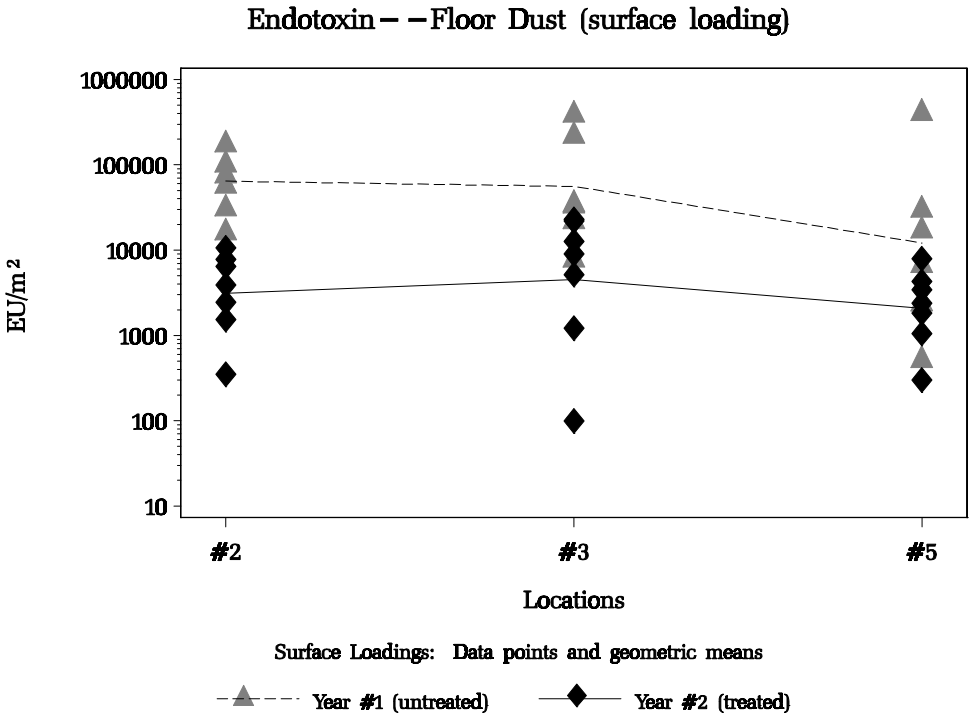
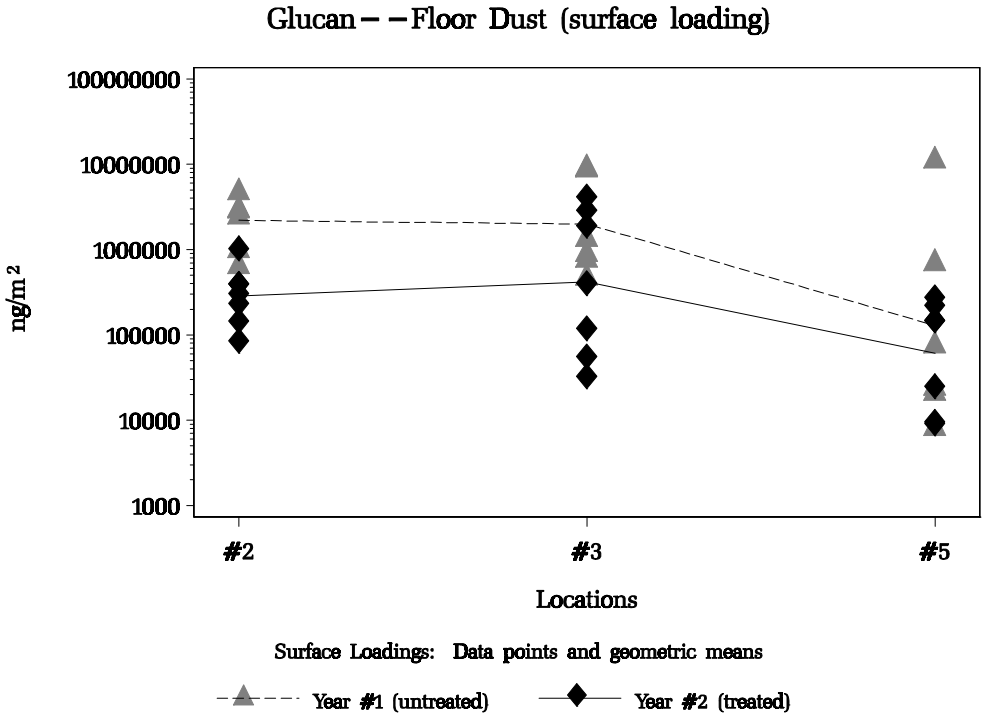
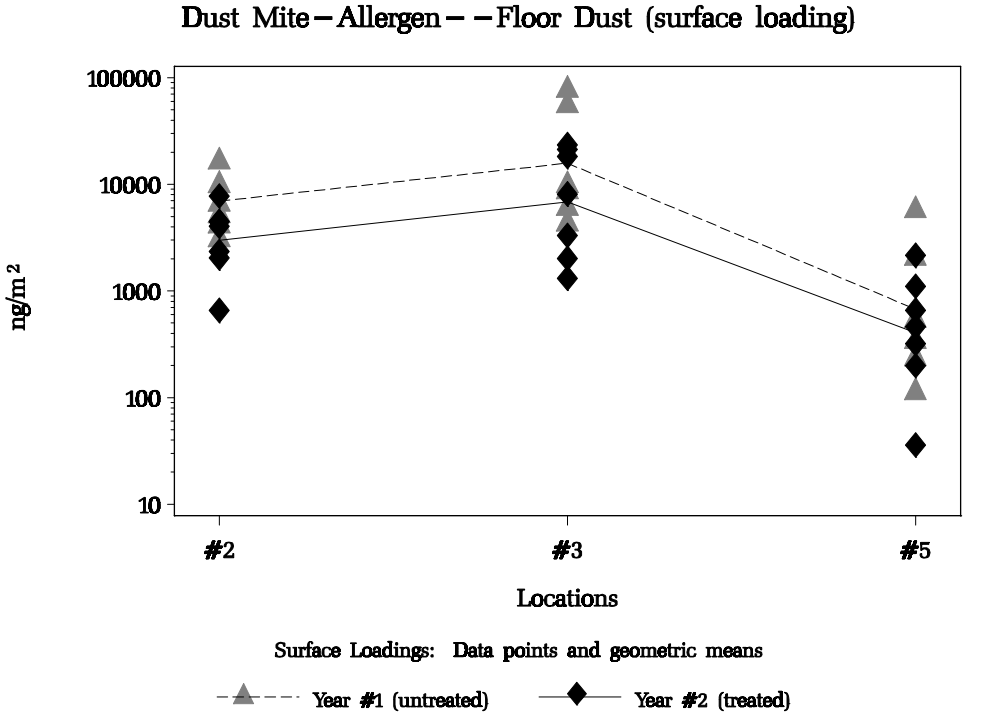
APPENDIX A

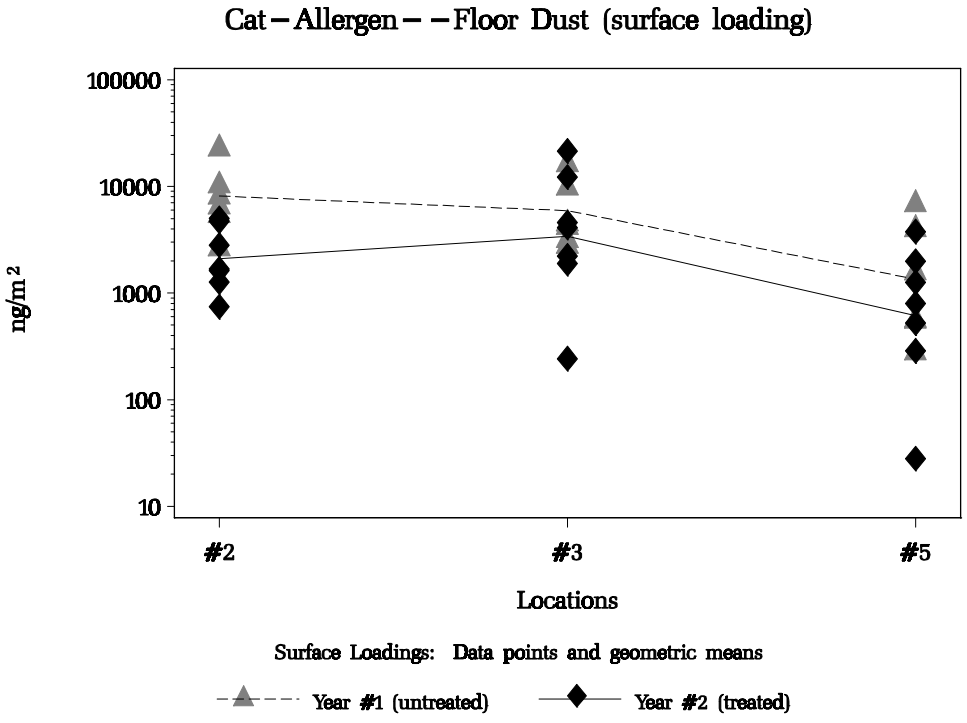
SURFACE LOADINGS

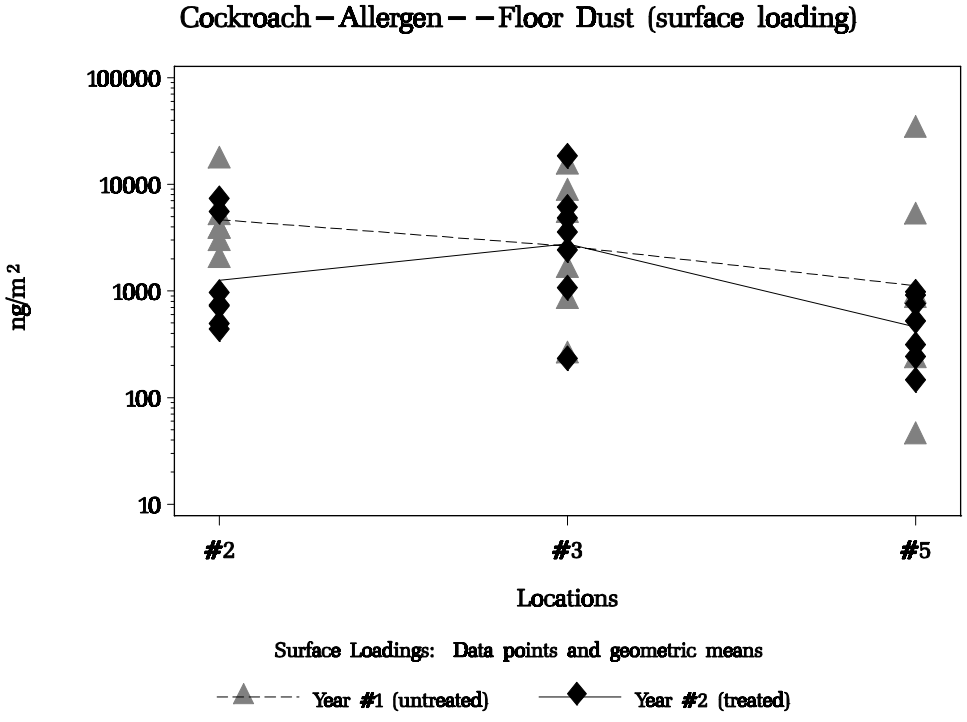


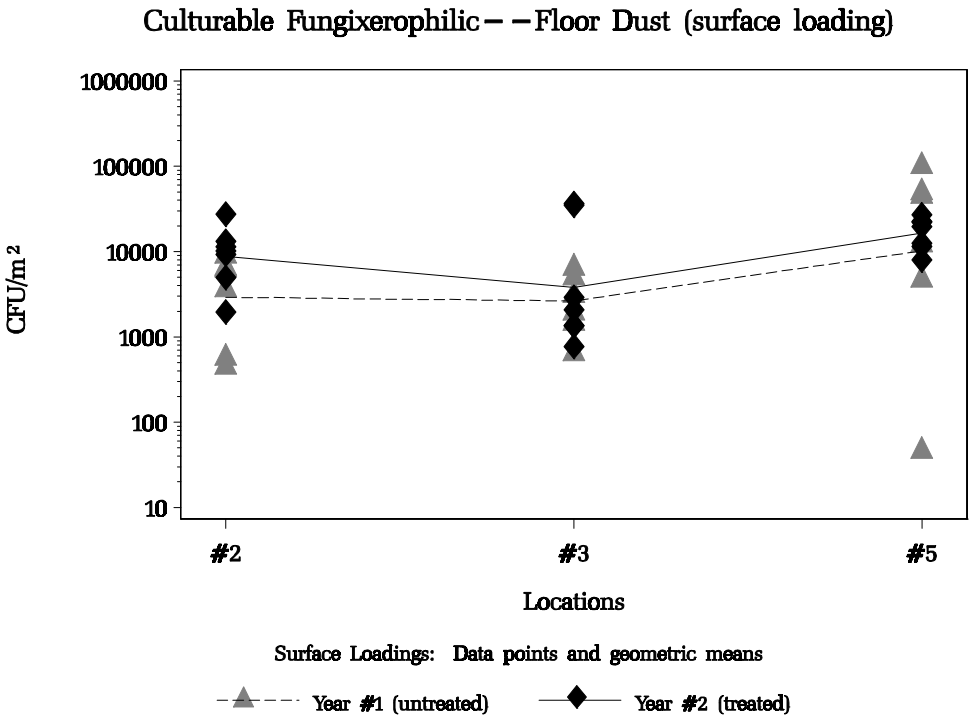



Glucan – –Floor Dust (surface loading)
100000000
10000000
1000000
100000
10000
1000
ng/m 2
#2
#3
#5
Locations
Surface Loadings: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)

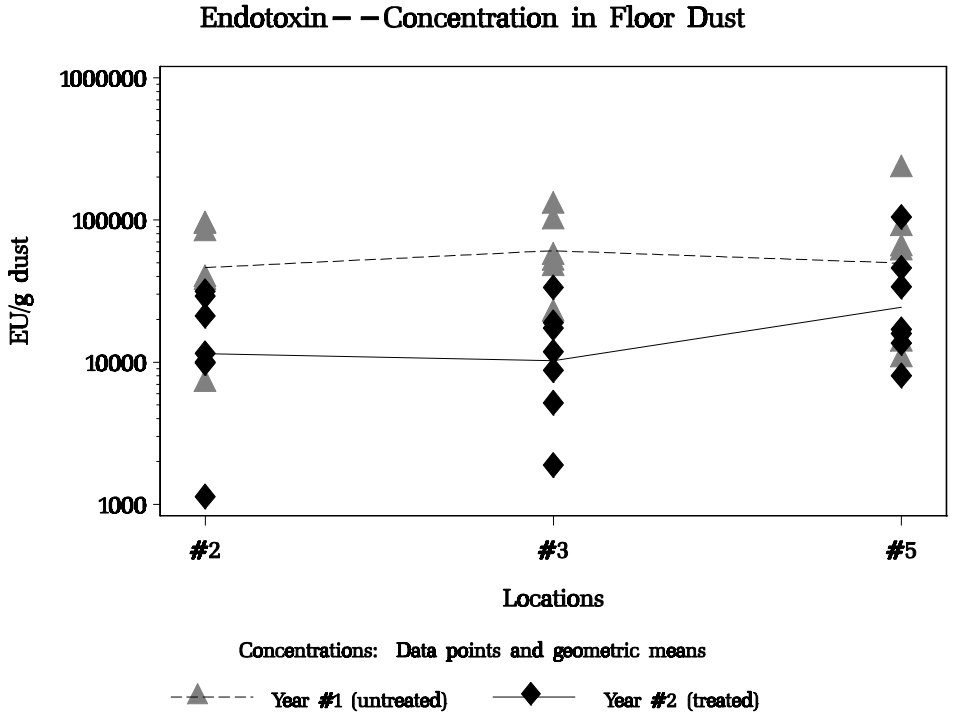

Dust Mite – Allergen – –Floor Dust (surface loading)
100000
10000
1000
100
10
ng/m 2
#2
#3
#5
Locations
Surface Loadings: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)

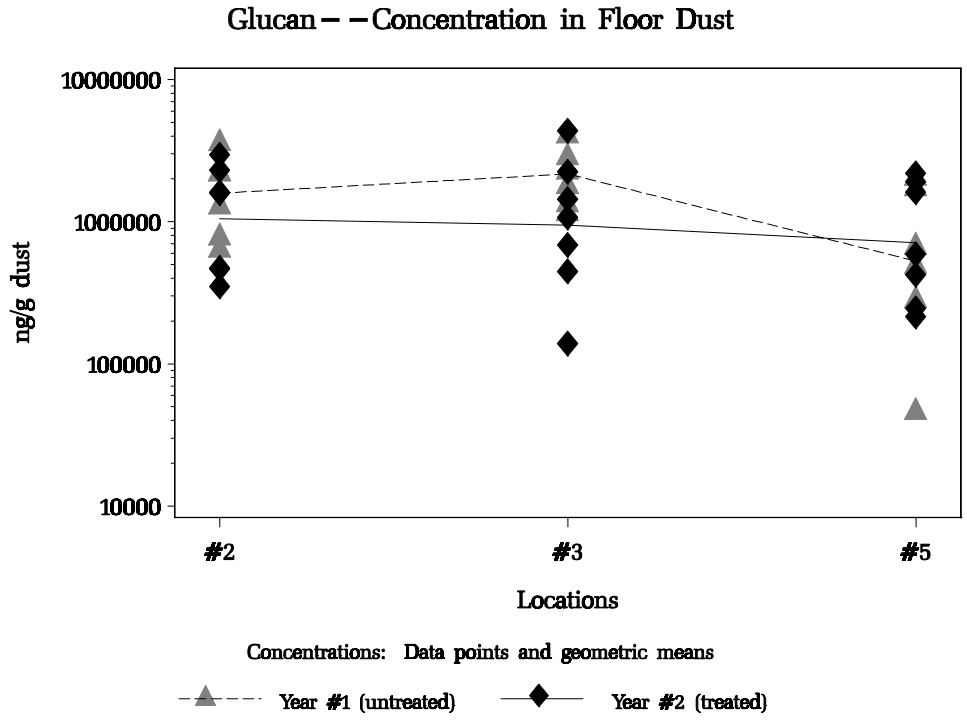

Cat – Allergen – – Floor Dust (surface loading)
100000
10000
1000
100
10
ng/m ²
#2
#3
#5
Locations
Surface Loadings: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)

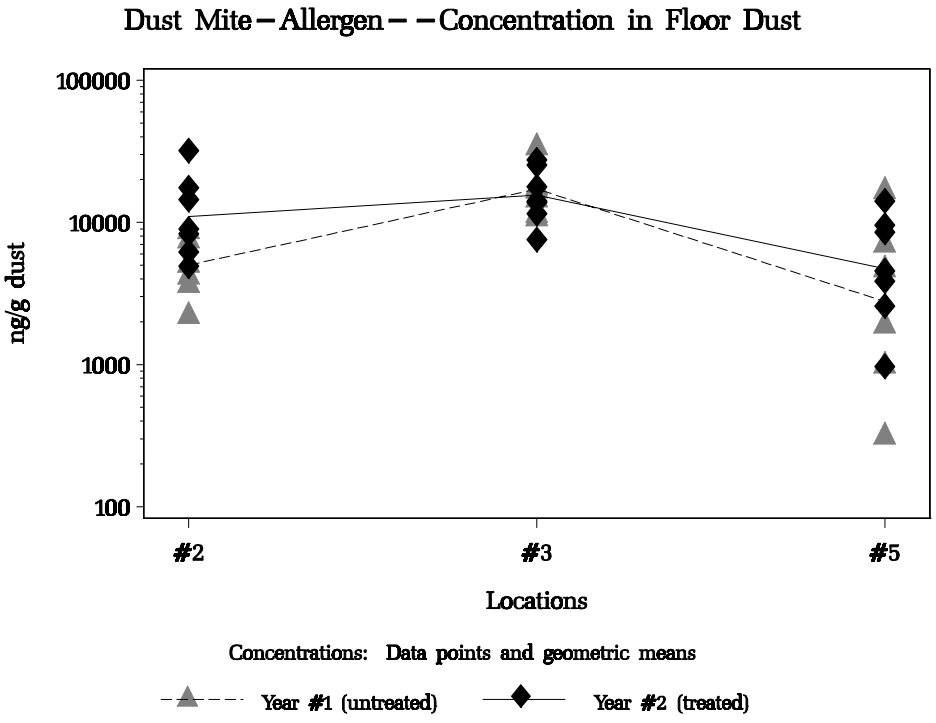

Cockroach – Allergen – – Floor Dust (surface loading)
100000
10000
1000
100
10
ng/m ²
#2
#3
#5
Locations
Surface Loadings: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)

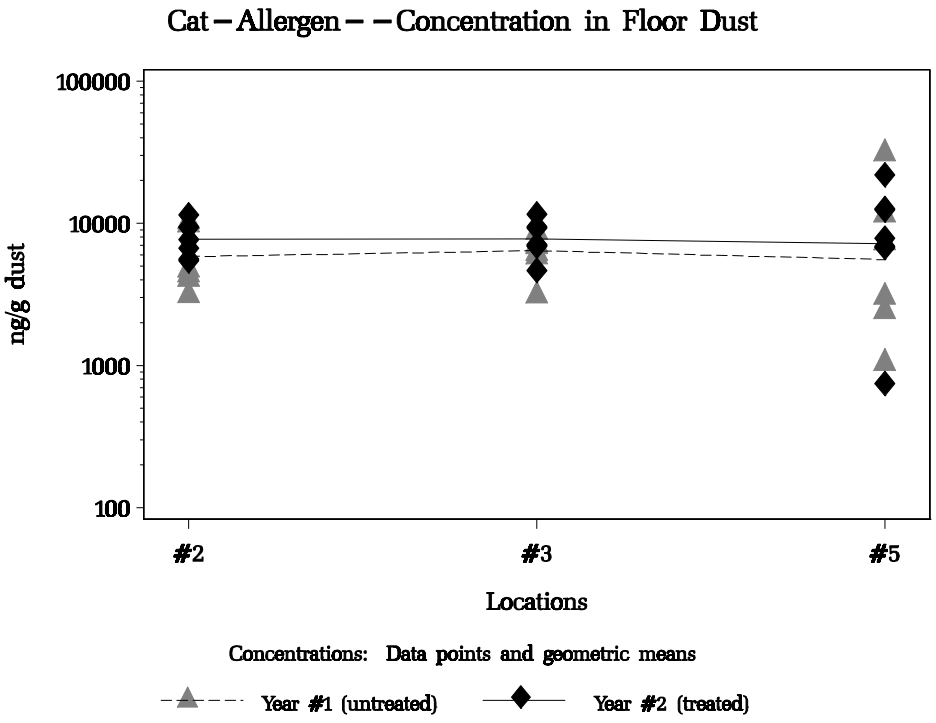

Culturable Fungixerophilic – –Floor Dust (surface loading)
CFU/m²
1000000
100000
10000
1000
100
10
#2
#3
#5
Locations
Surface Loadings: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)

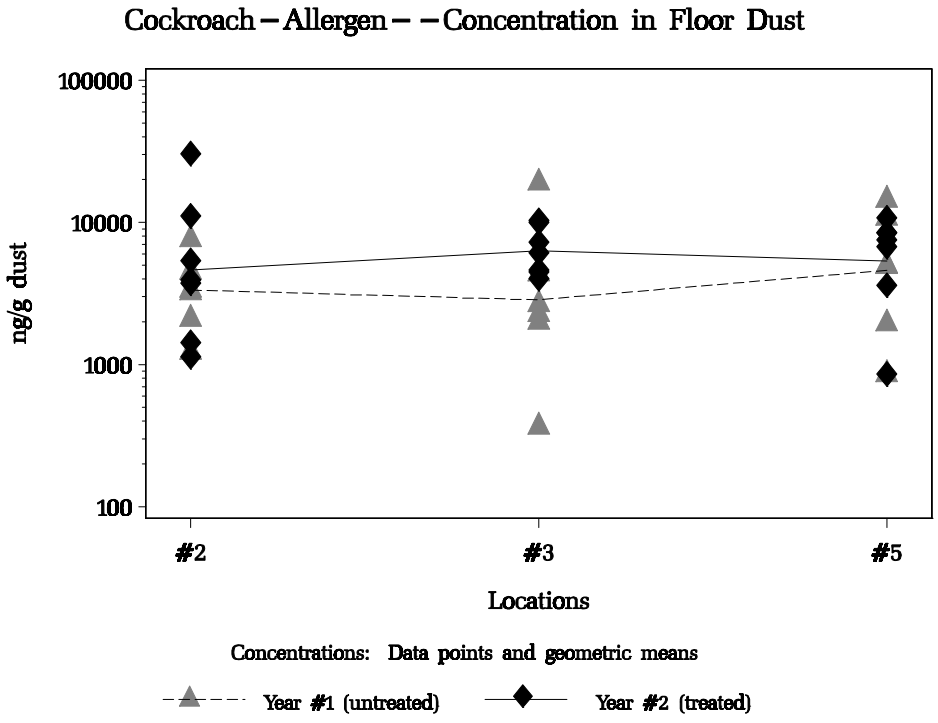
SURFACE CONCENTRATIONS

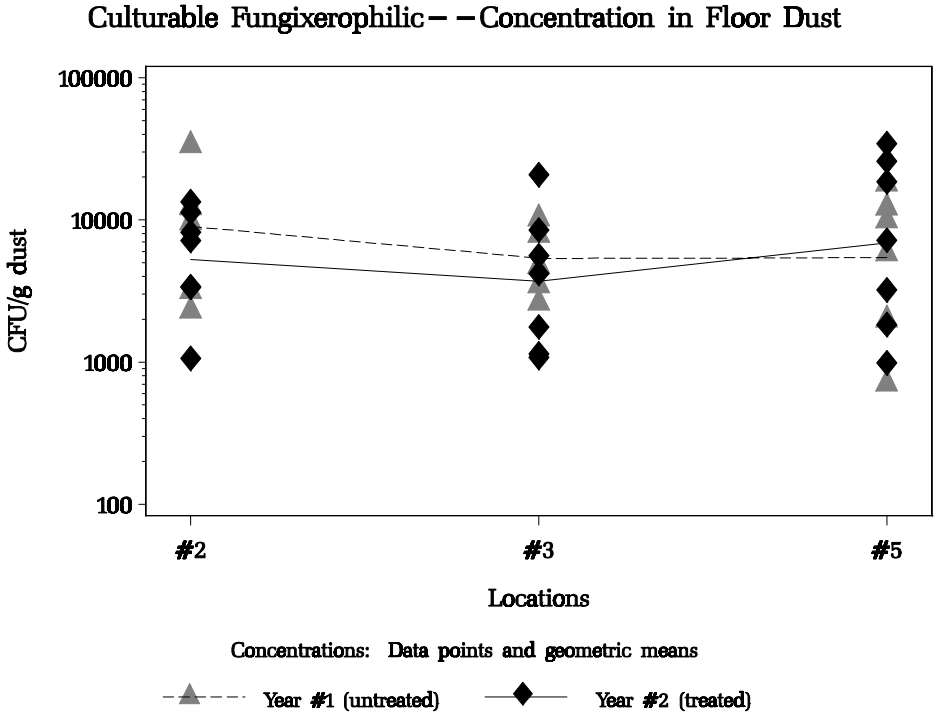





Dust Mite – Allergen – – Concentration in Floor Dust
100000
10000
1000
100
ng/g dust
#2
#3
#5
Locations
Concentrations: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)


Cat – Allergen – – Concentration in Floor Dust
100000
10000
1000
100
ng/g dust
#2
#3
#5
Locations
Concentrations: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)


Cockroach – Allergen – – Concentration in Floor Dust
100000
10000
1000
100
ng/g dust
#2
#3
#5
Locations
Concentrations: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)


Culturable Fungixerophilic – – Concentration in Floor Dust
100000
10000
1000
100
CFU/g dust
#2
#3
#5
Locations
Concentrations: Data points and geometric means
Year #1 (untreated)
Year #2 (treated)