Cases of Effective Carpet Cleaning

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ABSTRACT

There is a widespread misperception that carpet cannot be kept clean and that because of its inability to be kept clean, carpet contributes significantly to the deterioration of indoor environmental quality, especially unhealthy indoor air quality. This unnecessary misperception often leads to misguided decisions to remove carpet from many environments such as schools and health care facilities, while ignoring the effectiveness and environmental quality benefits of properly designed cleaning programs.

Carpet is a flooring product that contributes many direct positive features to the elevated quality of life indoors. In the long run, decisions to remove carpet as a response to ineffective cleaning not only deprive consumers and occupants of many desirable features provided by carpet, but simply transfer environmental problems related to cleaning breakdown to environments that do not have carpet.

INTRODUCTION

There are many reasons we clean any object, including carpet. The value of effective cleaning is magnified when we recognize cleaning accomplishes the following:

- Directly contributes to security, comfort, and productivity
- Allows for the reuse of space and materials
- Maintains the value of property and reduces the rate of depreciation
- Creates a unique psychology that enhances quality of life
- Encourages topophilia (*love of place*)
- Elevates a sense of well being which is the essence of good health
- Sends caring messages and image
- Promotes human dignity
- Accents aesthetics
- Manages waste and hazards and contributes to environmental protection
- Ensures sanitation—reduces adverse exposure levels
- Serves as a form of insurance that reduces risk and prevents crisis

Whether carpet or carpet cleaning-related businesses want to address the health issue or not, from a public policy and health perspective, sanitation and environmental risk management is high and will remain high on a list of reasons carpet goes or stays indoors, especially in sensitive environments like schools, hospitals, nursing and retirement homes.

As an environmental management tool, effective carpet cleaning must be focused on achieving specific objectives, especially those related to adverse exposure reduction, health protection, and maintenance of valuable property.

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As the green cleaning movement gains momentum, government guidance on cleaning will be forthcoming. Unfortunately, in the absence of science and testing, some of this bureaucracy-based guidance will work against the realities of cleaning science and make it very difficult to clean carpet, thereby preventing it from being a sustainable product indoors. Now is the time to deflect ineffective guidance, as well-intentioned as it may be, by embracing environmental management principles that have been shown to be effective and safe.

Carpet Cleaning Research

Overall, the health science literature indicates that carpet poses no risk to public health when it is clean. In addition, we have a body of science over the past 15 years that helps us better understand the impact of carpet and carpet cleaning activities on the quality of indoor environments. These studies point to the fact that there are scientific principles behind effective carpet cleaning and that carpet cleaning is an integral part of the overall environmental strategy necessary to keep indoor environments (environments where people spend the vast majority of their time) inviting, comfortable, productive, and safe.

Each study has significant contributions to an understanding of effective carpet cleaning.

The Denver study (1991). *The Denver study strongly suggests that professional carpet cleaning with the wet extraction method is the most effective process in reducing contaminant levels of bio-pollutants and particles. The "before" and "during" cleaning measurements of air pollutants show that the highest concentrations of airborne pollutants were associated with environments that that were moderately to heavily soiled, cleaned infrequently, or were cleaned with methods that had excessive chemical or particle residue. This central finding in the Denver research suggests that an effective cleaning program is critical to improving or maintaining indoor air quality, even though the focus on the study was limited to carpet cleaning.*

FPG Child Development Center study (1993-1994). *The FPG data demonstrates that both indoor and ambient environment pollution are significantly controlled through an effectively managed indoor cleaning program. In the FPG study the building was nearly 70% carpeted. The study reinforces a key finding of the 1991 Denver Study that carpeted environments that are frequently vacuumed and cleaned applying the "maximum extraction and minimum reside" principle are not expected to be associated with indoor air problems.*

Charles Young School study (2001). *The maintenance of a high-activity, city-center school emphasized effective vacuuming and scheduled extraction cleaning of all parts of the building including carpet. This cleaning program was found using environmental measures to be highly effective in keeping the school building healthy. An investigation found there were no unsanitary conditions or health complaints related to the building in any way. There were no indications of IAQ problems or student or teacher health response to allergens. Data collected in the most health sensitive portions of the building found that indoor pollution levels tended to be higher over hard surfaces than over carpet.*

The Anderson Creek School study (2001-2002). *The results showed 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 PM2.5 dust mass, dust mite and cat allergens, and culturable fungi, most probably indicating the holding strength of carpet. The extraction cleaning program resulted in reductions in the surface loading for all of the contaminants. 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.*

The Air Quality Sciences study of carpet cleaning (1999). *In this study, poorly maintained carpet from a high humidity/high temperature environment was cleaned and placed into a normal environment with humidity less than 65%. No mold re-growth was noted. After cleaning, test results from the previously contaminated carpet were comparable to those of a clean control carpet in terms of biocontaminants in the carpet and airborne particles.*

HydroLab mold study (2001). *The main conclusion of this research with respect to effective carpet cleaning is that the hot water extraction method of cleaning is highly effective in reducing the likelihood of mold growth and that clean carpet does not support mold growth even at prolonged and elevated temperature and humidity levels. It was clearly demonstrated that vacuuming carpet surfaces is highly effective in reducing and managing the levels of culturable mold spore. It is a conclusion for this project that for any organic material Dirt + Water = Mold Growth. The obvious management solution for mold indoors is to keep all carpet materials dry or at least clean.*

The Denver Study 1991

Very little quantified information exists in the scientific literature that indicates the contribution that carpet cleaning makes to the quality of indoor air. Some authors have speculated that dirty carpet, dusty surfaces, and polluted ambient environments are the primary sources of indoor air contaminants. However, there is very limited data that measures or quantifies the concentration of gas, particles, and bio-pollutants as they relate to sources indoors that are the object of cleaning, maintenance, and periodic restoration.

In a 1991 study conducted in Denver, air quality data were collected in 16 carpeted environments – 6 clerical offices, 5 service base offices, 5 residences, and 1 elementary school classroom. Air monitoring was conducted before and during professional carpet cleaning using the different methods widely available. Particles, gases, bio-pollutants, temperature, and relative humidity were all successfully measured.

The Denver data suggest that neglected and unclean carpet can be a significant source of biocontamination that can affect the quality of the indoor air. However, where carpet had been maintained on a regular basis with some form of extraction cleaning, no indication was found of poor indoor air quality or environmental degradation.

In general, carpet cleaning was not found to make a significant contribution to indoor air pollution. The possible exception is the short-term elevations of volatile organic compounds (VOCs) resulting from the use of chemical pre-sprays under pressure or spotting solvents used for very soiled carpet, and airborne particulate matter resulting from use of dry absorbent compounds.

When a wet extraction method was used, levels of VOCs, bio-pollutants, and particles during carpet cleaning were not significantly different from those detected before the cleaning. The highest concentrations of airborne contaminants generated during cleaning were associated with environments that were infrequently cleaned and had heavily soiled carpet. VOCs were highest where extensive detergent pre-sprays, spotting chemicals, and chemical solvents were needed to achieve pollutant breakdown before extraction.

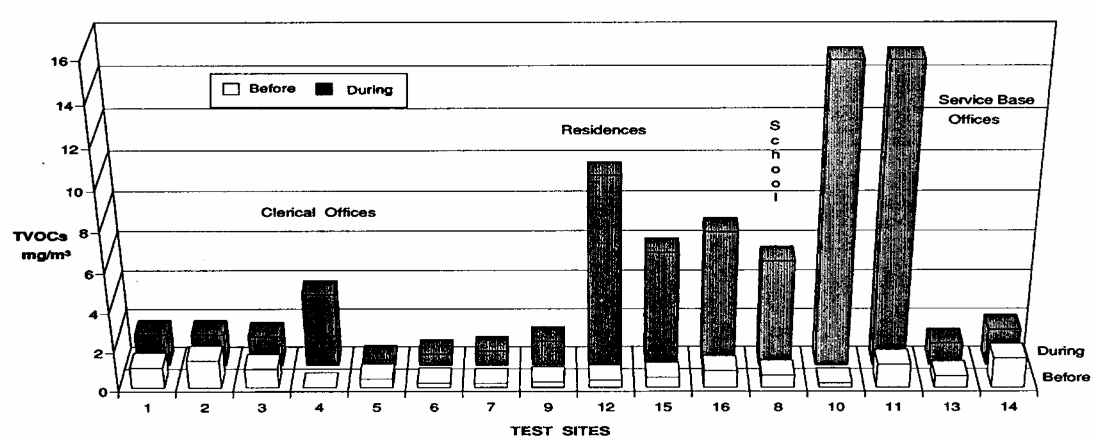

Figure 11A. Total Volatile Organic Compounds Collected on Tenax Before and During Carpet Cleaning

Airborne particles increased during initial vacuuming. Particle counts were higher in those environments that did not have a periodic carpet cleaning program. Particles that were generated, collected, and measured during cleaning with dry absorbent compounds were found to be of all sizes, including the respirable range (less than 10 microns in size).

The VOCs and particles generated during cleaning rapidly declined afterwards, provided there was sufficient ventilation.

Concentrations of airborne fungi and bacteria did not significantly increase or decrease during cleaning performed by a variety of methods. Fungi counts were significantly lower after extraction-type cleaning. The data suggests that the number of colony-forming units of bacteria or fungi is not as significant as the dominance of a particular species of bacteria or fungi. Large numbers of a particular species of fungi or bacteria were measured in environments where the carpet was not restored properly after experiencing water damage. Health complaints, where they existed, were normally associated with environments dominated by a particular species of a bio-pollutant.

The Denver study strongly suggests that professional cleaning with the wet extraction method is the most effective process in reducing contaminant levels of bio-pollutants and particles. The "before" and “during” cleaning measurements of air pollutants show that the highest concentrations of airborne pollutants were associated with environments that that were moderately to heavily soiled, cleaned infrequently, or were cleaned with methods that had excessive chemical or particle residue. This central finding in the Denver research suggests that an effective cleaning program is critical to improving or maintaining indoor air quality, even though the focus on the study was limited to carpet cleaning.

Table 11.11 Respirable (0.3 - 2.0µm) Aerosol Particle Measurements[1] (mg/m^3) Before, During, and After Each Carpet Cleaning Method

Method	Before	During Pile Lift		After [2]
DF	0.003	0.011		0.020
SHMP	0.001	0.022		0.003
BON	0.013	0.016		0.017
			During Raking	
HWE	0.021	0.067	0.090	0.043
			During Applying	
DA1	0.004	0.067	0.609	0.383
DA2	0.016	0.113	0.268	0.065

DF = Dry Foam
SHMP = Shampoo
BON = Bonnet
HWE = Hot Water Extraction
DA = Dry Adsorbent
1= The numbers reported are the averages from the specific time period for each method as reported in Appendix D.
2 = Measurements made within 10 minutes after cleaning

Table 11.13 Carpet Moisture Contents on the Surface and Underneath Before and After Each Cleaning Method

Site	Cleaning Method	Carpet Type	Percent Moisture [1] Before Cleaning Surface	Before Cleaning Deep	After Cleaning [2] Surface	After Cleaning Deep
1	DF	Nylon Short Plush	0	0	90	92
2	DF	Nylon Short Plush	0	0	84	86
	DF	Average	0	0	87	89
3	SHMP	Nylon Short Plush	0	0	99	100
4	SHMP	Level Loop Tile	0	0	84	84
	SHMP	Average	0	0	92	92
13	BON	Comm Level Loop	0	2	84	84
14	BON	Comm Cut Pile Loop	0	0	36	37
	BON	Average	0	1	60	60
5	DA1	Comm Level Loop	0	0	0	0
6	DA1	Comm Level Loop	0	0	0	0
10	DA2	Nylon Comm Cut	0	0	4	4
11	DA2	Nylon Comm Cut	0	0	3	10
	DA	Average	0	0	2	4
7	HWE	Nylon Cut Pile Saxony	0	2	47	58
8	HWE	Comm Loop	0	0	77	83
9	HWE	Plush Saxony	0	0	40	51
12	HWE	Plush Saxony	0	8	63	65
15	HWE	Nylon Plush Saxony	0	0	89	94
16	HWE	Nylon Cut Pile	0	0	98	98
	HWE	Average	0	2	69	75

1 = Readings for individual sites are averages from the data presented in Appendix F
2 = All "after" readings were taken when the entire cleaning process was completed
DF = Dry Foam
SHMP = Shampoo
BON = Bonnet
DA = Dry Adsorbent
HWE = Hot Water Extraction

Frank Porter Graham Child Development Center 1993-94

The primary objective in conducting research in the field of cleaning is to investigate the extent to which the cleaning process can measurably improve the quality of the built environment. In the Frank Porter Graham (FPG) study, the research focused on determining the extent to which cleaning affected indoor air quality.

The FPG study, coupled with its predecessor, the Denver Study, produced a data set which quantifies the concentrations of gases, particles, and bio-pollutants indoors as they relate to cleaning before, during, and after the cleaning activity under conditions where environmental management principles and guidelines have been adopted and applied.

The data from these studies indicate that an organized cleaning program based upon environmental management principles and fundamental environmental protection guidelines made a significant improvement in indoor air quality through the reduction of total suspended particulate (TSP) matter, total volatile organic compounds, and fungi and bacteria. The data demonstrates that both indoor and ambient environment pollution are significantly controlled through an effectively managed indoor cleaning program. In the FPG study the building was nearly 70% carpeted. The study reinforces a key finding of the 1991 Denver Study that carpeted environments that are frequently vacuumed and cleaned applying the "maximum extraction and minimum reside" principle are not expected to be associated with indoor air problems.

Cleaning should always follow fundamental environmental protection guidelines:

- Safety
- Cleaning for health first and appearance second
- Maximum extraction of pollutants (particles, gas, and bio-pollutants) from the building envelope
- Minimize chemical, particle, and moisture residue
- Minimize human exposure to pollutants
- Clean in relation to sanitizing the total environment
- Proper disposal of cleaning wastes.

In 1992, a year-long study was begun that evaluated indoor air quality in relation to cleaning activities in a building. Two floors of the building were dedicated to the care of preschool children and typified daycare environments found throughout the U.S.

Environmental guidelines for cleaning were applied. These guidelines were intended to maximize the primary cleaning objective of reducing human exposures to potentially harmful substances. The guidelines not only reduced exposures to indoor pollutants, they also constrained and helped establish effective cleaning methods and technology.

Many things that affect the quality of the indoor environment are currently being examined. These include the gaseous and particle emissions of products used indoors; the growth of microorganisms; intrusion of outdoor pollutants such as lead, pesticides and herbicides, ozone, and soil gases such as radon. Control methods designed to protect public health are also being studied. These include ventilation strategies, product management, and cleaning devices and systems.

In 1992, a year-long study was begun that evaluated indoor air quality in relation to general cleaning activities (carpet cleaning included) in a four-story, 26,000 square foot, non-complaint building. The building is located on the campus of the University of North Carolina at Chapel Hill and houses part of the University's medical research program. It is 70% carpeted.

All cleaning and maintenance of the building is done by the University's Housekeeping and Facilities Staff. The top floor of the building is similar to doctors' clinical offices; the third floor consists of administrative offices; and the two lower floors of the building are dedicated to the care of preschool children and typify a daycare environment. The childcare features of the building were of great interest to the research team since the environmental quality of daycare is currently of concern to medical and public health authorities, not to mention many parents.

In the study, environmental management principles and guidelines for cleaning were applied to cleaning in general. These guidelines are intended to maximize the primary cleaning objective of reducing human exposures to potentially harmful substances by extracting pollutants from the building.

The following indicates how environmental protection guidelines were applied to the North Carolina building as part of an improved cleaning program. These guidelines have been adopted by thoughtful, quality driven, and pro-active segments of the professional cleaning industry as an integral part of their cleaning standards (see IICRC Standard S001-1991). They are recognized as fundamental to sound indoor management practices.

Provide for safety

Cleaning was conducted in unoccupied environments. All toxic materials were kept away from adult occupants and children. All observed physical hazards were removed. Blood-borne pathogens were treated separately from other managed wastes in the building.

Clean for health first and appearance second

Effective disinfectants were used even though in some cases there was a bleaching effect on fabrics. In one instance where fungi were observed on an interior wall surface, the entire wall was removed to effectively control the bio-pollutant. At all times the primary objective of all cleaning conducted in the building was to guard the health of the occupants.

Maximize the extraction of pollutants from the building envelope

Maintenance staff was re-equipped with state-of-the-art vacuums for removal of particles. Vacuum bags with high collection efficiencies were used. Six months into the year-long study, high temperature hot water extraction was used to clean all carpet and rugs in the building. Routine dust collection was done with a damp dust cloth. Teachers were equipped with special wet-process cleaning machines to immediately clean after accidents.

Minimize chemical, particle, and moisture residue

After carpet cleaning, rapid drying was achieved through improved ventilation and, in some cases, fans. Dry cleaning powders were avoided to reduce indoor particle levels. Many VOC-based cleaning agents were replaced with water-based solutions. Extraction was improved with more efficient equipment and cleaning systems.

Minimize human exposure to pollutants

Nontoxic cleaning agents were used. Walk-off mats were placed at all entrances to trap pollutants. High efficiency filters in vacuums reduced human exposure during cleaning operations. Accidents in child care areas were cleaned immediately.

Clean in relation to improving the total environment

The ventilation system was balanced to improve air circulation through the building. Pests were controlled through the removal and proper storage of food in the building. Water-damaged areas of the building were identified, repaired, and restored. Cleaning was done in proportion to the level of human activity in the building.

Properly dispose of cleaning wastes

All cleaning wastes were properly disposed of in the sewage treatment or solid waste management system. Human wastes were managed separately from other wastes.

In addition to the above, effective activity management enhanced the quality of the environment, especially in daycare areas. In the course of the study, several standard operating policies and procedures were noted that are important to environmental health and safety. For example, because accidents occur at any time, daycare teachers were provided with equipment such as a wet vacuum that effectively extracted water from the environment whenever accidents occurred. Used diapers were separated from general trash. Housekeeping was organized so that diapers were disposed of as soon as possible, at least in the evening. Daycare teachers were given directions and the means to remove blood-borne pathogens, vomit, and other substances from carpet, hard surface floors, and furniture. Whenever beans, rice, or other food objects were used as learning toys, they were stored in tight containers to reduce pest pollution. All food items were stored in tight containers. Food spills were cleaned up as soon as possible. Containers for glue, diaper rash ointment, baby powder and other chemicals were tightly sealed and stored out of the reach of children. Loose staples, paper clips, scotch tape, and thumb tacks were removed from floors and working spaces.

The building studied was a non-complaint building. Cleaning procedures previously used by the University of North Carolina housekeeping staff were adequate to maintain a sanitary environment. However, when modest, cost-effective changes were made in the cleaning process and general operation of the building, the quality of indoor air improved markedly. Some environmentally-focused actions that were added to the normal cleaning process are believed to have contributed significantly to improving the indoor air quality. They included:

- The restoration of water-damaged parts of the building (including the removal of all building materials contaminated by bio-pollutants) was accomplished immediately upon discovery. This action is an example of source control and design intervention at work.

- The state-of-the art high efficiency vacuum cleaners and bags were provided to the cleaning staff. Removal of pollutants is at the heart of cleaning and cannot be done without good technology.

- Hot-water extraction cleaning methods and technology were employed in the deep cleaning of all carpet and rugs throughout the building. When done correctly as specified in professional carpet cleaning standards (IICRC S001-1991), this method of professional carpet cleaning extracts the greatest amount of pollution from an indoor environment and leaves the least amount of cleaning residue compared to other methods. It is important to note that drying occurred completely in all regions of the building within four to eight hours of the carpet cleaning activity.

- Surface dusts were removed with damp mops and dust cloths. Dusts were effectively contained and removed from the environment using this technique.

- Some cleaning agents were replaced with materials containing fewer volatile organic compounds. This is an example of source management: if you remove the source of VOC from the building, you will not find it in the air.

- Interior door mats were installed to trap and collect particles at entrances. As mentioned previously, this is an effective means of controlling pollution at its source (outdoor particles trapped at the door).

- The building's ventilation system was inspected to verify air flow through the building. Effective ventilation contributes to the dilution and removal of particles and gases.

It is important to know that these actions were not extraordinary in any way. They did not add to cleaning or labor costs. They were a standard practice in the market place and part of the budget for routine maintenance. The main difference from the usual cleaning activity was that these actions emphasized pollution reduction or extraction and were integrated into the cleaning plan and carried out on time.

FPG Results

Air quality was measured throughout the building on a monthly basis beginning in July 1992 and ending in July 1993. Baseline data was collected between July and December 1992. All floors of the building were deep cleaned in late December 1992 and placed on a modified cost effective cleaning program (discussed previously). Air quality measurements were taken for six months following the deep cleaning.

Total suspended particulate (TSP) matter was reduced from a building average of 11 ug/m3 before implementation of the cleaning program to an average of 5.7 ug/m3 six months after the program was put into effect, representing a 52% improvement. Given the low concentration of particles the building began with, a 52% improvement in particle concentration is very dramatic and attests to the contribution of the extraction techniques and technology used in the modestly modified cleaning program. Airborne particles were reduced through the use of high efficiency vacuum bags and cleaners, damp dusting methods, frequent dusting and vacuuming, and walk-off mats. Dust measured as total suspended particulate matter (TSP) in the indoor air correlated strongly with fungi and bacteria measured in air. In other words, the higher the concentrations of total suspended particulate matter, the higher the levels of airborne bacteria and fungi. Also, contact measurements of bacteria and fungi on non-floor surfaces correlated strongly with bacteria and fungi found in indoor air. This suggests the importance of frequent removal of dust from shelves, file cabinets, tables, and high reach areas if particles as well as bio-pollutants in indoor air are to be reduced.

Total Volatile Organic Compounds (TVOC) concentrations were reduced in the building as the result of lower emitting cleaning agents and possibly the removal of hydrocarbon during carpet cleaning. Average TVOC concentrations were 324 ug/m3 before the cleaning program was put into effect. After the program was implemented, the TVOC 6-month average was 165.7 ug/m3, a 49% improvement.

Airborne bio-pollutants as a class were greatly reduced as a result of the cleaning program. There was a 40% improvement of airborne bacteria and a 61% improvement in airborne fungi. Elevated concentrations of gram negative bacteria, penicillium, and actinomycetes are strong indicators of a problem building, as well as the absence or ineffectiveness of an existing cleaning program. Penicillium and actinomycetes were improved about 90% and essentially eliminated as the result of the cleaning program. The random isolated occurrences of elevated concentrations of fungi (penicillium) that have the potential to sensitize humans suggest the need for frequent, effective cleaning to keep the building under control. Although the common bacteria bacilli were not found to necessarily be a good indicator of cleaning effectiveness, airborne concentrations of aspergillus, cladosporium, and bacillus were also improved by about 20% in the course of the study. Improperly restored water-damaged environments are a common source of bio-pollutants known to have an adverse effect on humans. In this regard, relative humidity in the North Carolina Study strongly correlated with airborne fungi counts. Fungi levels were markedly higher when the moisture content of the air was high. The elevated levels of penicillium found in the study were associated with moisture damage. When the water-damaged portion of the building was restored, significant levels of penicillium were not detected.

1993-94 Study of Frank Porter Graham Child Development Center
University of North Carolina at Chapel Hill

Air Pollutant Category (Building Means)	**Routine Housekeeping (5 Months)**	**Improved Housekeeping (7 Months)**	**% Change**	**Most Probable Contribution to Improved Air Quality**
DUST				- Efficient Vacuum Cleaners and Bags
Airborne mass (ug/m^3)	12 (3-31)	6 (1-13)	-50%	- Walk-off Mats - Damp Dust Cloths
Carpet mass(g/m^2)	1.8 (0.1-11.6)	2.3 (0.2-9.9)	28%	- Frequent Vacuuming and Dusting
Laser particle count (10^6 Particles/m^3) >0.5 um	1.3 (0.28-3.8)	1.4 (0.44-3.6)	8%	- Deep Cleaning of Entire Building - Dust Control on Hard Surfaces
TOTAL VOC (ug/m^3)	324 (88-530) (3 months)	166 (29-309)	-49%	- Cleaning Chemicals with Less VOC - Extraction from carpet - Balanced Ventilation System

BIO-POLLUTANTS				- Rapid use of Disinfectants After Accidents - Control of Food and Perishables - New Extraction Equipment - Hot Water Extraction of Carpet - Moisture Control - Removal of Contaminated Sources (Wall, Rotten tree stump) - Walk-off Mats
Airborne Bacteria (CFU/m^3)	395(71-855)	237 (34-868)	-40%	
Airborne Fungi (CFU/m^3)	127(22-406)	50 (2-219)	-61%	
	204 (1-2060)	32 (1-230)	-84%	
Carpet Dust				
Bacteria (100,000 CFU/g)	15 (0.2-42)	9 (1-24)	-40%	
Carpet Dust Fungi (10,000 CFU/g)				

Charles Young Elementary School 2001

There has been limited opportunity to measure educational performance in relation to a healthy school environment. Charles Young School provided such an opportunity.

There are several measures for evaluating environmental and educational performance in schools. Environmentally, we can measure temperature, humidity, and noise levels. We can measure cleaning effectiveness and sanitation levels especially for IAQ, bacteria and mold. We can look at health and accident reports. Educationally, we typically measure long-term academic achievement in math and reading. We can also measure absenteeism, student perception of the school environment, discipline incidents, and parent involvement and support. We can measure teacher attitudes, retention and transfer rates.

General Environmental Factors

Environmental Factors	**Before Restoration**	**Post Restoration** **Y 2000**	**Observation**
Temperature and Climate	Broken HVAC, 60°-100 °F, steam leaks, ineffective ventilation	Comfortable 68 ° -72 ° F Controlled humidity	HVAC system effective in comfortable temperature
Lighting	Many dim areas and widespread glare	Well lighted school and reduced glare	New windows and soft flooring reduce glare
Health and Safety Hazards	Electrical hazards Trip hazards	No hazards	Restoration removed all know hazards
Teaching Space	Space limited by deterioration and unsanitary surfaces	Open, flexible use of all surfaces	Much flexibility in teaching space achieved by restoration
Maintenance Practices	Maintenance was ineffective in the face of widespread deterioration	Scheduled, effective equipment, attention to extraction, safe disinfectants	Motivated staff, cleaning plan and schedule, effective technique and equipment achieves a constant sanitary condition
Furnishings and Decor	Generally uninviting	Colorful, soft and appealing	New furnishings create a high sense of comfort and well-being
IAQ	Lead, high dust, toxic VOC	No toxic pollutants, fully acceptable air quality	See table
Bio-pollutants	Excessive mold,	No or very low bio-	See tables

	bacteria, allergens	pollutant levels detected	

The school and its educational strategy depend on an environment that is attractive comfortable, open, free of glare and noise. The inviting open classroom design of Charles Young Schools has been demonstrated to provide a well lighted, comfortable environment, highly effective in developing the educational performance of students.

Carpet floor coverings are essential in making the classrooms work. For example, student reading skills have greatly improved because of open classes and flexibility of teaching associated with total usable space that includes the floors. An ability to communicate between student and teacher is possible only with good sound control. Classrooms at Charles Young have estimated sounds levels that range been 58 and 65 db. Normal speech can be heard easily throughout the school building. The use of carpet in the Charles Young School makes satisfactory sound control simple and economical to achieve. Research has shown that “without carpet, effective sound control in open space classrooms is virtually impossible to achieve” (School Facilities and Transportation Division, State of California, 1986).

The school environment is healthy and sanitary as measure by standard public health methods. A summary of air and other environmental data collected on behalf of the Carpet and Rug Institute for the school year 1998-1999 strongly suggests that the indoor environment of Charles Young School is properly maintained and exhibits no sign or traits of an unsanitary environment or of an IAQ problem building.

Maintenance of the school emphasized effective vacuuming and scheduled extraction cleaning of all parts of the building including carpet. This program is highly effective in keeping the school building healthy.

Extensive environmental data were collected three times during the school year 1998-1999, including data for all the bio-pollutants that have the greatest health risks indoors: fungi, gram negative bacteria, and cat, mite, and cockroach allergens. Respirable suspended particulate matter and total volatile organic compounds (TVOC) were also measured. Numerous measurements were taken in the surrounding outside environment throughout the school building.

Environmental quality data were collected in the most health-sensitive portions of the building: the fully carpeted Pre-K kindergarten area and the hard floor surface lunch room. In addition, no region of the building indicated significant deviation from acceptable environmental quality levels such as those shown in the table below. IAQ levels, none of which would indicate a problem, tended to be higher over hard surfaces than over carpet. This finding reinforces and validates the decision to replace carpet throughout the building for comfort and noise control.

Summary of Environmental Quality for School Year 1998-1999

Location	**June 1998**	**December 1998**	**June 1999**	**Observation**
Outdoor AQ Fungi	460-780 CFU/m^3	490 CFU/m^3	610-1020 CFU/m^3	Normal range no dominant species
IAQ Fungi Over Carpet (Pre-K)	250-260 CFU/m^3	180-240 CFU/m^3	670-1640 CFU/m^3	Normal range no problem in relation to outside
IAQ Fungi Over Hard Floor(Lunch R)	270-720 CFU/m^3	440 CFU/m^3	290-510 CFU/m^3	Slightly higher counts than over carpet
Fungi Carpet Surface Pre-K	<20 CFU/cm^2	<20 CFU/cm^2	<20 CFU/cm^2	Normal
Fungi Hard Floor Surface	<20 CFU/cm^2	<20 CFU/cm^2	< 20 CFU/cm^2	Normal
Outdoor AQ Bacteria	<10 CFU/m^3	10 CFU/m^3	20 CFU/m^3	Normal

IAQ Over Carpet Bacteria	40 CFU/m^3	<10 CFU/m^3	<10 CFU/m^3	Normal in relation to outside
IAQ Over Hard Floor Bacteria	210 CFU/m^3	20 CFU/m^3	40 CFU/m^3	Normal but higher than carpet
Bacteria (gnb) Carpet Surface	<4 CFU/cm^2	<5 CFU/cm^2	< 5CFU/cm^2	Sanitary
Bacteria (gnb) Hard Floor	23 CFU/cm^2	<5CFU/cm^2	<5CFU/cm^2	Unsanitary 6/98 measurement
RSP Outdoors	35 ug/m^3	22ug/m^3	29ug/m^3	Normal City RSP AQ
RSP Over Carpet	33 ug/m^3	15ug/m^3	32ug/m^3	Normal RSP IAQ in relation to outside
RSP Over Hard Floor	64 ug/m^3	40 ug/m^3	40ug/m^3	Elevated, <40 desirable
TVOC Over Carpet	31.4 ug/m^3	152 ug/m^3	35.6 ug/m^3	No problem likely
TVOC Over Hard Floor	24.1 ug/m^3	93.6 ug/m^3	87.9 ug/m^3	No problem likely
Airborne Cockroach Allergen(Pre-K)	<0.01 U/m^3	<0.01 U/m^3	<0.02 U/m^3	No problem likely for any allergen (cat, mite, cockroach)

*Collected and Submitted to the Carpet and Rug Institute by Air Quality Sciences, Inc., 1999.

A high level of housekeeping and maintenance is essential in making the classrooms work. In August 2001, prior to the school-year cleaning of the facility, a cleaning effectiveness analysis was conducted throughout the building with a focus on the sanitation condition of flooring. A pre-sampling investigation found no health complaints related to the building in any way. There were no indications of IAQ problems or student or teacher health response to allergens. An environmental cleaning effectiveness sampling technique used widely in the food sanitation and food processing industry was applied throughout the building to a variety of flooring materials prior to their cleaning. The sampling methods for both bacteria and fungi are economical but at the same time highly effective in detecting unsanitary conditions as indicated by gram negative bacteria and mold growth.

Fungi Analysis Charles Young School (August 2001)

Location	**Before Cleaning**	**After Cleaning**	**Observation**
Auditorium Carpet	<5 CFU/cm^2(Yeast)	<3 CFU/cm^2(Yeast)	High humidity is cause of yeast
Hard Floor Hallway 1st Floor	5 CFU/cm^2(Yeast)	N/A	Carpet and hard floor levels were equivalent
Principle's Office Carpet	5 CFU/cm^2(Yeast)	<2 CFU/cm^2(Yeast)	No problem
Open Class 2nd Floor Carpet South w/ failed humidifier	6 CFU/cm^2(Yeast)	< 4 FU/cm^2(Yeast)	No problem
Open Class 2nd Bay	6 CFU/cm^2(Yeast)	n.d.	Cleaning highly effective in removing

Carpet South Side			yeast
Hard Floor Hallway 2nd Floor	6 CFU/cm^2(Yeast)	N/A	2nd floor carpet and hard floor yeast levels equivalent

Gram Negative Bacteria Analysis Charles Young School (August 2001)

Location	Before Cleaning	After Cleaning	Observation
Lunch Room	n.d.	N/A	Very Sanitary
Principle's Office Carpet	1 CFU/cm^2	n.d	High traffic area but very clean before cleaning
Open Class 2nd Floor Carpet South	1-3 CFU/cm^2	3 CFU/cm^2*	Small section of carpet cross contaminated with condensation water
Open Class 2nd Floor Carpet South w/ failed humidifier	6-8 CFU/cm^2	1 CFU/cm^2	Carpet cleaning reduced bacteria count

(*At the time samples were collected, a dehumidifier malfunction released contaminated water onto a small portion of the carpet floor. This water contained high levels of gram negative bacteria. The problem posed no health risk and was corrected, but this event shows the need to keep all parts of an environment clean and dry and free of water intrusion.)

The levels of measured bacteria and yeast exhibit no sign of an unsanitary or problem building even at a time of year the building's cleaning state was stressed by year of continuous use and at a time in the Washington, D.C. summer when relative humidity levels remained at levels in excess of 90%.

Anderson Creek School 2001-2002

Cost-effective cleaning technology and scheduled cleaning is the key to maintaining carpet in schools. The purpose of this project was to demonstrate the hypothesis that effective extraction cleaning will remove allergens in carpet that has not been properly maintained. As demonstrated by the Frank Porter Graham study, airborne concentrations of allergens will be significantly reduced (50%+ likely).

The field portion of this project began in May 2001 and was a follow-up to the RTI project measuring allergens in carpeted and non-carpet schools. In this project, we used a school with carpet for which we had baseline data set. At the end of the spring semester and the beginning of summer break 2001, we equipped the school with an effective extraction and cost- and labor-effective carpet cleaning program and schedule.

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 (ref dlf paper). It 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 non-problem 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 pre-cleaning baseline assessment followed by a thorough building cleaning to eliminate potential pollutant sources. The cleaning included professional deep cleaning, training of housekeeping staff, and the provision of new equipment. The cleaning was followed by a seven-month post-cleaning characterization. The results showed that an organized cleaning program based on environmental management principles could contribute to measurably better control of biocontaminant sources in a building.

Two recommendations came out of the Anderson Creek Study. One was the study recently completed to compare biocontaminant levels in carpeted and non-carpeted environments. 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 non-problem, non-complaint carpeted building. Because children spend so many hours in school, the school environment is particularly important and the prevention of bio-contamination 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 carpet.

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 reduce the existing workload required to maintain the carpet. Any increase in responsibilities or workload would not be cost-effective, and therefore would not fit 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 environmental health 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 reside. 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 collected 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 only one contaminant might potentially 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 fungi, 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. Endotoxins were 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 PM2.5, 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 PM2.5 airborne dust sample.

The school was a non-complaint, non-problem, carpeted elementary school. The school was situated in rural locations 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 smooth surface. 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 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.

The cleaning program was developed by Dr. Michael Berry of the University of North Carolina at Chapel Hill, Mr. Buzz Cohen, and Mr. John Downey. The following describes the program.

Training was conducted as a three-step process: instruction, demonstration, and hands on experience.

Vacuuming- Focus was on 1) learning operation of new vacuums, 2) ensuring they were in proper working order, and 3) instituting 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.

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.

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:

1. Pre-inspect
2. Pre-vacuum
3. Pre-spot
4. Precondition
5. Agitate
6. Dwell time
7. Extraction
8. Grooming
9. Drying

Cleaning Equipment and Supplies

As with spotting, each cleaning-team member received a laminated sheet covering the cleaning system. Following is a list of cleaning equipment and supplies:

4- Windsor Versamatic, model VS18 (CRI Green Label tested)
3- Steamin Demon II High-Flow extractors
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)

Recommendations

Other than the improvements in training, 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.

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.

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.

Anderson Creek School Results and 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 improvements in the form of 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 PM2.5 dust mass, dust mite and cat allergens, and culturable fungi, indicating the holding strength of carpet.

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 ($p < 0.05$)

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 extraction 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.

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)

The keys to a successful cleaning program are 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.

Increasingly, schools are in use year-round. Their cleaning requirements are as intense and frequent as any high-use office complex. With regards to the proper maintenance of floor surfaces, the following applies: carpet requires less time and equipment than traditional hard surfaces. BOMA published statistics to show that cleaning cost is reduced in relation to carpeted environments. BOMA estimated maintenance in carpeted environments to cost $0.64 per square foot of flooring as compared to $1.24 per square foot for VCT. The independent cost analysis done as part of this assessment came to same general conclusion ($1.38 per square foot for VCT and $0.83 per square foot for carpet in a 12 month school year operation). In addition, there are a number of hidden costs and environmental life cycle considerations including water use, chemical use, residue disposal, storage, and labor stress, all of which are considerably higher for hard surface floor maintenance than for carpet maintenance.

Air Quality Sciences Carpet Cleaning Research 1999

A 1999 study of the impact of soiled carpet on the indoor environment by Air Quality Sciences (16) of Atlanta examined the role of environmental conditions on the potential for biocontaminant re-growth following cleaning. In this study, poorly maintained carpet from a high humidity/high temperature environment was cleaned and placed into a normal environment with humidity less than 65%. No mold re-growth was noted. After cleaning, test results from the previously contaminated carpet were comparable to those of a clean control carpet in terms of biocontaminants in the carpet and airborne particles.

SUMMARY OF AIRBORNE CHEMICAL/PARTICLE DATA
PHASE 2/ELEVATED CONDITIONS (80-85°F, 80-90% RH)
METHOD: HOT WATER EXTRACTION

ANALYTE	BACKGROUND	BEFORE CLEANING	DURING AND AFTER VACUUMING	DURING AND AFTER CLEANING	12 HOURS AFTER CLEANING
Total VOCs (μg/m³)		46	63	86	33
Primary VOCs (μg/m³)		Ethane, 1,1,1-trichloro (39.5) Dodecane (5.8) 1,3-Butadiene, 2-methyl* (2.8)	Ethane, 1,1,1-trichloro (36.0) 1,3-Butadiene, 2-methyl* (16.2) 2-Propanol (Isopropanol) (10.8)	2-Propanol, 1-(2-methoxy-1-methylethoxy)* (38.3) Acetaldehyde (36.5) Ethane, 1,1,1-trichloro (11.9)	Ethane, 1,1,1-trichloro (26.5) Dodecane (6.6) Ethanol (5.6)
Particles (μg/m³)					
Respirable - Average	10	60	42	6	2
Respirable - Range	nd-15	30-128	nd-61	nd-23	nd-8
Total - Average	12	80	50	8	6
Total - Range	nd-23	35-130	8-75	nd-28	nd-20

Average values presented with (standard deviation of measurement).

SUMMARY OF AIRBORNE MICROBIAL DATA
PHASE 3/EXTREME CONDITIONS (80-85°F, 80-90% RH)
PREVIOUSLY CLEANED CARPET/ METHOD: HOT WATER EXTRACTION

ANALYTE	BACKGROUND	BEFORE CLEANING	DURING AND AFTER VACUUMING	DURING AND AFTER CLEANING	12 HOURS AFTER CLEANING
Allergens (ng/m³)					
Mite	nd	nd	nd	nd	nd
Total	nd	9	nd	nd	nd
Fungi (CFU/m³)	20	2.3 x 10³	1.9 x 10³	843	71
Primary type	Penicillium	Aspergillus	Aspergillus	Aspergillus	Cladosporium Aspergillus

Average values presented with (standard deviation of measurement).

SUMMARY OF MICROBIOLOGICAL CARPET DATA
PHASE 3/EXTREME CONDITIONS (80-85°F, 80-90% RH)
PREVIOUSLY CLEANED CARPET/METHOD: HOT WATER EXTRACTION

ANALYTE	BEFORE CLEANING	AFTER VACUUMING	12 HOURS AFTER CLEANING	2 WEEKS AFTER CLEANING		4 WEEKS AFTER CLEANING	
				65%	85%	65%	85%
Dust Allergens (ng/cm²)							
Mite	1.2	0.08	0.06	nd	0.04	nd	nd
Cat	0.02	nd	nd	nd	nd	nd	nd
Cockroach	nd	nd	nd	nd	nd	nd	nd
Dust Fungi (CFU/cm²)	9420	6220	520	619	8100	432	7948
Primary species	Aspergillus	Aspergillus	Aspergillus	Aspergillus	Aspergillus	Aspergillus	Aspergillus

Average values presented with (standard deviation of measurement).

Mold and Carpet Research - HydroLab 2001

Mold growth on carpet, VCT, ceiling tiles, and drywall were studied in four phases of highly controlled, elevated temperature and humidity exposures between April and December of 2001.

In phase 1 of the study, 16 test beds of new and soiled carpet and VCT, along with standard ceiling tile and drywall were exposed to a continuous temperature of 80°F and relative humidity of 65% for a period of 21 days. As expected, no mold colonies were detected on any of the materials.

In phase 2 of the study, the same test materials were exposed to an elevated climate of 80°F and 80% relative humidity. It was anticipated that at these conditions mold would grow rapidly (< 21 days) on all organic materials. Surprisingly, it was not until 5 weeks of continuous exposure at high and extremely uncomfortable indoor temperature and humidity levels that mold growth appeared, and only on dirty portions of test materials and the wood holding the drywall.

Comparison of Mean Total CFU Phase II (80^{o}F/80%)

Chambers	Product	CFU/ 33cm^2			
		Day 0	**Day 7**	**Day 21**	**Day 63 - after wetting with ½ L water on Day 42**
Chambers 1-4 New carpet	ceiling tile	2.1	1.0	0.5	10
	dry wall	0.4	1.7	1.6	7
	new carpet	20.9	20.4	8.5	> 88.6
	wood studs	NM	NM	NM	TNTC
Chambers 5-8 Used carpet	ceiling tile	1.8	1.1	0.1	10
	dry wall	1.6	0.6	1.2	6
	used carpet	17.9	12.8	14.3	TNTC
	wood studs	NM	NM	NM	> 71
Chambers 9-12 New VCT	ceiling tile	1.2	0.3	0.2	9
	dry wall	0.4	1.5	0.3	17
	new tile	7.6	2.6	4.1	TNTC
	wood studs	NM	NM	NM	> 18
Chamber13-16 Used VCT	ceiling tile	0.8	0.4	0.2	4
	dry wall	1.7	0.8	0.4	4
	used tile	8.2	3.3	1.7	> 162.75
	wood studs	NM	NM	NM	> 61

All eight (8) carpet samples were cleaned with clean hot water alone. Temperature of the water was estimated at 170^o-190^o F. Water was extracted. For new carpet this step removed dusts. For old carpet, this step began to breakdown all water soluble materials and remove loose materials. A cleaning chemical (surfactant) was applied only to the 4 dirty carpet samples and allowed to dwell for 5 minutes. Cleaning solution was worked into the carpet with a carpet rake. This step was intended to help separate water-soluble dirt from fiber. The four old carpet were cleaned with hot clear water and extracted a second time. A glue spot was removed from carpet sample Chamber 8 using tricloroethane. All solvent was extracted from the carpet. Extremely soiled areas of dirty carpet were again treated with surfactant. The solution was allowed to dwell for 5 minutes and agitated with a carpet rake. All residues were extracted from the carpet with clean hot water.

In phase 3, a source of *Aspergillus glaucus* (*Asp.g.)* provided a uniform spore deposition on all test materials. This particular species of mold suggests that the most likely source of spore deposition was from mold growth on wet wood framing material holding drywall in the test beds. Important to any investigation of effective carpet cleaning, however, was the finding that after two months of exposure, there was no induction of active mold growth on any of the cleaned (old or new) carpet samples.

Phase III Sampling Contaminated Chambers (CFU/ 33cm^2) *Asp.g.*

Chamber	Flooring 8/14/2001	Drywall 8/14/2001	Ceiling Tile 8/14/2001	Flooring 9/19/2001
Chamber 1 New clean carpet	60	20.5	47	89
Chamber 2 New clean carpet	32.5	40.5	33	79.5
Chamber 3 New clean carpet	21.5	8	41.5	85.5
Chamber 4 New clean carpet	6.5	31.5	24.5	79.5
Chamber 5 Old clean carpet	30	27	1	76.5
Chamber 6 Old clean carpet	76.5	TNTC	TNTC	65.5
Chamber 7 Old clean carpet	48	TNTC	42	61.5
Chamber 8 Old clean carpet	30.5	7	3.5	73.5
Chamber 9 New VCT	37.5	11.5	5	241
Chamber 10 New VCT	30	17.5	10.5	134
Chamber 11 New VCT	79	42.5	17	121.5
Chamber 12 New VCT	56.5	22	31.5	132
Chamber 13 Old VCT	TNTC	TNTC	40.5	146
Chamber 14 Old VCT	54.5	12	10	157
Chamber 15 Old VCT	27	25.5	26	150.5
Chamber 16 Old VCT	36	42	20.5	151.5

In phase 4, the test area was rebuilt and only clean flooring materials (4 new carpet, 4 old carpet, 4 new VCT, and 4 old VCT) were exposed to the elevated climate of 80^{o}F and 80% relative humidity. Naturally deposited mold spore was vacuumed from all flooring materials. After two months of exposure there was no increase in spore count or any indication of mold growth on carpet or VCT.

Phase IV Time Line of Events

9/19/2001	9/21/2001	10/10/2001	10/20/2001	10/29/2001	11/30/2001
Outdoor exposed 16 floor samples placed in test area 80^{o}F/80%	Baseline sampling found high counts of *cladosporium* and *epicoccum*	1st Vacuuming of floor samples	2nd Vacuuming of floor samples	Sampling found very low CFU mold	Sampling found very low CFU mold

Samples of all flooring were collected after vacuuming on October 29, 2001 and November 30, 2001. Results of that sampling show a radical decrease in detectable mold spore. There was no indication of mold growing on any of the 16 flooring samples at elevated humidity levels for a period of two months.

Phase IV Sampling Results ***CFU/ 33cm²***

Chamber **80F/80%**	**Flooring**	**Order Sample Placed into Research Area 9/19/2001**	**Baseline 9/21/2001**	**Sampling** **10/29/2001**	**Sampling** **11/30/2001**
Chamber 1	New clean carpet	8	89	1.66	2
Chamber 2	New clean carpet	7	79.5	2.6	1.33
Chamber 3	New clean carpet	6	85.5	1.66	1
Chamber 4	New clean carpet	5	79.5	3	1
Chamber 5	Old clean carpet	4	76.5	0.33	2.33
Chamber 6	Old clean carpet	3	65.5	3.66	1
Chamber 7	Old clean carpet	2	61.5	8	7.66
Chamber 8	Old clean carpet	1	73.5	4.3	0.66
Chamber 9	New VCT	16	241	7.1	8.66
Chamber 10	New VCT	15	130.5	4.6	8.33
Chamber 11	New VCT	14	121.5	13.3	5.33
Chamber 12	New VCT	13	132	10.6	6
Chamber 13	Used VCT	12	146	5.3	9.66
Chamber 14	Used VCT	11	157	9.6	13
Chamber 15	Used VCT	10	150.5	7.6	9
Chamber 16	Used VCT	9	151.5	26.6	13.33

Conclusion

The main conclusion of this research is that the hot water extraction method of cleaning is highly effective in reducing the likelihood of mold growth and that clean carpet does not support mold growth even at prolonged and elevated temperature and humidity levels. It was clearly demonstrated that vacuuming carpet surfaces is highly effective in reducing and managing the levels of culturable mold spore. It is a conclusion for this project that for any organic material Dirt + Water = Mold Growth. The obvious management solution for mold indoors is to keep all carpet materials dry or at least clean.

Appendix A

The Pennsylvania Green Building Operations and Maintenance Manual

CARPET CARE – GENERAL MAINTENANCE

Action Items:

1. Ensure that vacuums are in good working order using appropriate bags and/or filters.
2. Empty or replace vacuum bags when half full and dispose of them properly.
3. Clean up spills while they are still fresh.
4. Minimize the amount of moisture used during cleaning.

The procedures for carpet care in a green maintenance program are similar in most instances with those of a traditional program. Beyond the traditional issues, carpet care in a green maintenance program addresses the selection of the appropriate products and equipment (see section on product selection), along with some minor modifications of the procedures themselves.

In a green maintenance program the primary effort should be a pollution prevention strategy, or one that minimizes the need to extract a carpet. Thus, a specific focus should be on preventative measures, such as:

1. Keep outside/outdoors entryways clean to prevent soils from being tracked into the facility. This may include sweeping, use of a power sprayer, etc.
2. Use entry mats to capture soils and moisture from shoes. It is preferable that the mats be large enough for each shoe to hit the mat two times (approximately ten to twelve feet).
3. Frequent vacuuming of entryway mats and grating systems.
4. Frequent dust mopping of resilient tile floors, especially close to entryways and other sources of particulates (i.e. near copier rooms) to reduce soiling on surrounding carpeted areas.
5. Establish a specific daily routine for cleaning carpet.
6. Establish an interim cleaning process to address the needs of high traffic areas.
7. Minimize the need for large scale extraction cleaning.

When carpet needs to be spot cleaned, solutions should be applied from a sprayer in a stream or coarse spray, as compared to a fine mist. This will minimize the amount of material that is atomized and potentially inhaled, as well as minimize over-spray. When carpet needs to be extracted, it is important that occupants be notified. It is preferable to use the least toxic products possible. Use the least amount of water and ventilate the area with fans if necessary for rapid drying to minimize both the possibility of mold growth and slip-fall incidents.

It is preferable to conduct major cleaning activities on a weekend or some other extended time period when occupants will not be in the facility. This allows maximum time for the building to be ventilated (flushed with fresh air) prior to the return of the occupants.

CARPET CARE – EXTRACTION CLEANING

1. Minimize the amount of cleaning chemicals. Excess chemicals result in rapid resoiling.
2. Use appropriate, functioning equipment that will maximize the amount of water being extracted from the carpet to minimize moisture and potential for mold, mildew and bacterial growth.
3. After extraction of carpet areas that were flooded, spray-treat the area with a disinfectant solution (e.g., Micro-Ban) to prevent mold, mildew, and bacteria growth.
4. Increase ventilation, open windows if weather allows, and use fans to dry carpet quickly. Carpet should be completely dry within 24 hours.
5. Dispose of cleaning solutions properly.

Carpet can act as a “sink” allowing particles and other unwanted material to filter down into the backing of the carpet. Once deep down in the carpet this can lead to damage of the fibers and the need to ultimately replace the carpet. But from a health perspective, the biggest enemy of a healthy indoor environment occurs when moisture provides an opportunity for these unwanted contaminants to become biologically active. Extraction cleaning can get deep down into the carpet and remove the unwanted contaminants.

Unfortunately, extraction cleaning can also add large amounts of water to the carpet, especially if the equipment is not functioning properly. Select appropriate cleaning solutions (see section on product selection). Mix cleaning solution properly. Using too much concentrated cleaner not only wastes product but can lead to more rapid resoiling of the carpet. Do not apply too much solution.

Make sure that the vacuum pick-up is working properly and that there are no holes or leaks in wands or other attachments that decrease suction. When vacuuming up spent solution, repeat the process multiple times in both directions.

Use increased ventilation to help dry carpet. This can be accomplished by opening windows when weather permits, increasing building ventilation and using floor level drying fans. Carpet should dry within 24 hours to minimize the potential for bacteria and other potentially harmful organisms to grow.

Occupants should be notified before large-scale extraction procedures are used as this activity can affect more sensitive individuals. Proper scheduling is recommended when building is not to be occupied such as before weekends and holidays. Building should also be ventilated or flushed with fresh air prior to being reopened.

REFERENCES

1. Air Quality Sciences, Inc., Carpet Cleaning and Acceptable Indoor Air Quality: A General Review of Carpet Cleaning Effectiveness, June 1999.
2. Berry, M.A. Assessment of Carpet in Sensitive Environments, May 2001.
3. Berry, M.A. Healthy School Environment and Enhanced Educational Performance: The Case of Charles Young Elementary School, Washington, DC, January 2002.
4. Berry, M.A. Final Report of the Hydrolab Project 2001-Flooring, Humidity, and Mold Growth, March 2002.
5. Berry, M.A. The Contribution of Restoration and Effective Operation and Maintenance Programs on Indoor Environmental Quality and Educational Performance in Schools, Proceedings: Indoor Air 2002, Monterey California, July 2002.
6. Berry, Michael A. Protecting the Built Environment: Cleaning for Health for Health, Tricomm 21st Press, Chapel Hill, N.C. pg. 185. 1993.
7. Berry, Michael A., Carpet and High Performance Schools, January 2003.
8. Bishop, L. J. More Answers Than You Have Questions about Carpet Cleaning, Vols. 1 & 2. Dothan, AL: Clean Care Seminars, 1991.
9. Canadian Facility Management & Design, “When Clean is Not Green,” April 2002.
10. Cole, E, et al. Indoor Air Quality Monitoring in Carpeted Environments. March 1992.
11. Foarde, K. Franke, D. RTI, Research Triangle Park, NC, Berry, Michael A., University of North Carolina at Chapel Hill, Cleaning Effectiveness Demonstration in a Carpet School, November 2002.
12. Foarde, Karin, M Berry, A Comparison of Biocontaminant Levels Associated with Hard vs. Carpet Floors in Non-problem Schools: Results of a Year Long Study, Proceedings: Indoor Air 2002, Monterey California, July 2002.
13. Franke, Deborah L., et. al., Cleaning for Improved Indoor Air Quality: An Initial Assessment of Effectiveness, Indoor Air, The International Society of Indoor Air Quality and Climate, Vol 7: 41-54, 1997.
14. IICRC Carpet Cleaning Standard, S001-1991. Standard Reference Guide for Professional on Location Cleaning of Installed Textile Floor Covering Materials. Vancouver, WA: International Institute of Cleaning and Restoration Certification, 1991.
15. Indoor Air Quality Monitoring in Carped Environments, Environmental Criteria and Assessment Office, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1992.
16. Indoor Environment Characterization of a Non-Problem Building: Assessment of Cleaning Effectiveness, Environmental Criteria and Assessment Office, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1994.

17. Institute of Medicine, Indoor Allergens Assessing and Controlling Adverse Health Effects, National Academy Press, Washington D.C., 1993.
18. Spivak, Dr. Steven, University of Maryland - A Preliminary Assessment of Indoor Air Quality Issues Related to Textile Furnishing and their Professional Cleaning, literature review for USEPA, 1989
19. Turiel, Issac. Indoor Air Quality and Human Health. Stanford: Stanford UP, 1985.
20. U.S. Environmental Protection Agency, Indoor Environment Characterization of a Non-Problem Building: Assessment of Cleaning Effectiveness, 1994.