FINAL REPORT OF THE HYDROLAB PROJECT 2001
FLOORING, HUMIDITY, AND MOLD GROWTH

PREPARED FOR THE CARPET AND RUG INSTITUTE

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EXECUTIVE SUMMARY

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

In phase 1, 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, 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.

For phase 3, all carpet materials were cleaned and exposed to the extreme climate of 80°F and 80% relative humidity. In this phase, 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 was from mold growth on wet wood framing material holding drywall in the test beds. After two months of exposure, there was no induction of active mold growth on any of the cleaned (old or new) carpet samples.

In phase 4, the test area was rebuilt and only clean flooring materials (4 new carpets, 4 old carpets, 4 new VCT, and 4 old VCT) were exposed to the elevated climate of 80°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.

The main conclusion of this research is that clean carpet does not support mold growth even at prolonged and elevated temperature and humidity levels. It is a conclusion for this project that for any material Dirt + Water (High Humidity) = Mold Growth. The obvious management solution for mold indoors is to keep all carpet materials dry or at least clean.

INTRODUCTION

The objective of this research is to the study the behavior of mold growth on building products flooring, walls, ceiling tile that are commonly found in schools and other sensitive environments when exposed to both normal and elevated temperature and humidity levels. The general hypothesis tested in this work is that molds grow in high

humidity, > 80% relative humidity, on dirty materials and materials constructed with organic nutrients. In this research we are particularly interested in comparing new clean and used heavily soiled carpet with new and used hard floors (VCT).

The scientific literature indicates mold tends not to grow readily at humidity levels 65% and below (Burge H.A. 1995). In this work we examine the hypothesis that new or clean nylon carpet does not support mold growth, even at elevated humidity levels, where other products by virtue of their organic material composition and soil burden tend to more readily support mold growth in highly moist environments.

DISCUSSION

There is every indication in the environmental and public health literature that moisture control as it affects mold growth and indoor environmental quality and the human condition will receive an increased attention and scrutiny in the next few years, especially as it relates to growing concern over asthma (USEPA 2002). The professional cleaning and restoration industry has long recognized the importance of effective cleaning and rapid drying to ensure mold management. This research reinforces and encourages the principle of "clean and dry" because it is critical to the successful management of indoor environments, mold, and ultimately health protection (IICRC 1999).

Environmental literature over the past 50 years indicates that carpet has on different occasions been the target of unfounded environmental health concern. A recent review of the literature finds that carpet related reports exhibit a history of wrong conclusions, i.e., VOC, 4-PCH, health problems in homes and schools (Berry 2001).

The National Academy of Medicine Report, "Indoor Allergens" (Institute of Medicine 1993), is often cited with regard to removing carpet from indoor environments. NAS documents carry enormous weight in the medical and environmental health communities. Examples of misrepresentation include:

"Carpets are installed over padding, traditionally felted jute……."
Jute is not used as padding and has not been used for over 30 years.

"Carpets have been characterized when wetted as 'cultivation' media for microorganisms (Gravesen et al., 1983)."
This reference is often cited as the reason carpet is taken out of various environments.

National Education Association's *Healthy School Handbook*, Chapter 9, School Floor Coverings (NEA 1995), is very biased when it comes to carpet in schools. The author cites without qualification the discredited work of Anderson (1992). The author also cites the NAS "Carpets have been characterized when wetted as 'cultivation' media for microorganisms" which is noted above. The author indicates incorrectly that maintenance of hard surfaces is far lower than carpet flooring. The facts are just the opposite. The author ends her chapter with the following: "If the number one priority of a school system is the health of the students and staff, the decision will be to install hard-surface floors." This conclusion is fully inconsistent with the findings of this research.

The American Lung Association, "Achieving Healthy Indoor Air" publication (American Thoratic Society 1997) states: "The benefits of carpets include acoustic control, soft surface, and protection against trauma, thermal insulation, durability, attractiveness, and resilience. However, carpets can be reservoirs for allergens and growth environments for house dust mites and molds. To date, these concerns about carpets have related to their uses in homes, offices, and schools, and particularly to their being sources of biologic particulate antigens."

The American Lung Association report goes on to state that carpet is a "growth environment for house dust mites and molds. Dirt accumulates over time, rendering the carpet a favorable medium for the growth of molds. Carpets in basements, bathrooms, and other areas prone to moisture are likely sources of molds. Carpets laid on concrete slab-on-grade are also subject to trapping of moisture below the carpet, which is a potential source of microbial contamination."

Mold is only one biological component of the complex ecology of the indoor and outdoor environments. Molds share many characteristics with yeasts, mushrooms, mildews which makeup a group of organisms distinct from plants and animals called fungi. All fungi depend on external sources of non living organic (carbon based) material for energy and their body form (skeletons). Approximately 70,000 species of fungi have been identified. It has been estimated that 1.5 million exist (Gravesen S. *et al.* 1994).

Fungi survive by decomposing living or nonliving organic matter. Their main purpose in the web of life is to decompose and recycle nature's debris (Du Temple L.A. 2000). Always where we have wet organic debris we find fungi, especially mold. Fungi and their abundance depend on the availability of organic nutrients, water, and temperature. Fungi have an absolute requirement for water but exhibit a wide range of tolerance in relation to water availability. Fungi can survive over a broad temperature range 50-104 degrees F. However optimum growth tends to be found in the range 56-86 degrees F.

Fungi reproduce through the formation of spores. Spores contain one to many cells and differ greatly in size, shape, color and method of formation. Spores are microscopic ranging in size from less than 2um to 100um, with the vast majority of spores being less than 20um. Most fungal spores are adapted for airborne dispersal. Fungal spores germinate to produce fungal colonies that eventually produce and release a new generation of spores.

Fungal colonies produce and excrete a vast number of metabolites in addition to spores. Literally thousands of these metabolites have been chemically characterized and include a range of antibiotics, mycotoxins, and alkaloids. These metabolites have both benefits and risks to humans. Beneficial medicines, harmful poisons, and carcinogens derived from fungi are well known by the health protection community and the general public. Gas phase metabolites, commonly referred to as volatile organic compounds (VOC), excreted from fungi are often detected in the form of unpleasant odors such as the "moldy" smell associated with damp basements and crawl spaces (ACGIH 1999).

Mold spores are everywhere, including the indoor environment. Under wet conditions, spores germinate and mold colonies grow and multiply. Excess moisture and the availability of organic nutrients is the underlying cause of indoor mold problems. Common indoor moisture sources include: Humidifiers, cooking and dishwashing, bathing, plumbing leaks, house plants, firewood storage indoors, improperly vented clothes dryer/indoor clothes line, and combustion appliances. Common outdoor sources of moisture include: Roof leaks, flooding, rain or snowmelt, seasonal high humidity, ground moisture, and wet building materials (MDH 2001).

The purpose of our research is to examine the growth of mold on materials carpet, VCT, ceiling tiles, drywall) commonly found in schools and other sensitive environments and to provide information that either verifies previous conclusions such as those noted above or provide the accurate perspective and conditions for such conclusions. It is the main thesis of our work that the key to prevention and correction of mold problems indoors is effective moisture control and cleaning.

METHODS AND RESULTS

The research was conducted between April and December 2001 at HYDROLAB, 20799 Riverwood Ave., Noblesville, IN 46060. In all four phases of this investigation, the laboratory was employed by Carpet and Rug Institute. Sixteen (16) chambers were used simultaneously in 4 test periods lasting 1-3 months each. In each test period of differing relative humidity (65% and 80%) mold growth was measured by a standard contact method, identified and quantified (CFU/cm^2) for 6 specified locations in each chamber at days 1, 7 and 21 days of the period. Research Triangle Institute (RTI), an independent non profit laboratory, advised on the microbiology, prepared and provided sampling materials, and read and counted mold growth on all contact plates. (DG18 was selected as the sampling media because it is primarily designed for the xerophilic fungi--those able to grow at the lower elevated humidifies. Penicillia, Aspergilli can be readily identified.)

Shaw Industries supplied all the flooring materials (new carpet, old unclean carpet, new hard flooring, soiled hard flooring, standard adhesives) and directions for installation for each of the 16 chambers.

HYDROLAB provided materials and labor to build, paint and install wall sections for each chamber, and materials and labor to form, pour and install concrete flooring slabs 2’x 4’x 3 ½”. Concrete was cured for 20 days in advance of test. HYDROLAB installed flooring supplied by Shaw Industries (carpet and VCT). Also provided by HYDROLAB were equipment and staff to monitor moisture content, temperature and humidity in test area, photographing process, documentation on moisture content, temperature and humidity readings, staff to provide documentation for chain of custody tracking, labor for incubator teardown, disposal and cleanup. An onsite microbiologist was subcontracted by HYDROLAB to monitor environmental conditions, observed biological activity, collect, record, and ship samples, coordinate with Research Triangle Institute’s biological laboratory, received and shipped plates to RTI for analysis.

Table 1. Configuration of Chambers Phases I & II

Chambers	***Contents***	***Phase 1***	***Phase 2***
Chambers 1- 4	Clean new carpet on concrete, drywall coated with water base paint, and ceiling tiles	Temp 80° F Humidity 65%	Temp 80° F Humidity 80%
Chambers 5-8	Never cleaned 8 year old carpet on concrete, drywall coated with water base paint, and ceiling tiles	Temp 80° F Humidity 65%	Temp 80° F Humidity 80%
Chambers 9-12	Clean VCT on concrete, drywall coated with water base paint, and ceiling tiles	Temp 80° F Humidity 65%	Temp 80° F Humidity 80%
Chambers 13-16	Used dirty VCT on concrete, sheet rock coated with water base paint, and ceiling tiles	Temp 80° F Humidity 65%	Temp 80° F Humidity 80%

Table 2. Phase I and II -Sampling Regime for Each of 16 Chambers on Days 1, 7, 21

Phase	***Floor***	***Ceiling***	***Drywall***	***Total Plates***
Temp 80° F Humidity 65%	2	2	2	288
Temp 80 ^{o}F Humidity 80%	3	3	3	432
Total Samples				720

There was continuous monitoring of temperature and humidity in the lab containing the 16 chambers. The temperature and humidity of lab in which the incubators were located were recorded continuously during each testing period. Photographs documenting the research were taken through the research project.

RTI advised on all microbiology sampling, evaluation, recording, and data interpretation. RTI provided the standard contact plates with appropriate quality control, and a qualified microbiologist to determine colony-forming units per sample.

RESULTS OF PHASE 1 AND 2

The initial result (Phase 1) of the project was as expected. Insignificant growth was measured on any product when exposed to humidity levels of 65%.

Table 3. Phase 1 Mean Total CFU Isolated at 65% RH

Chamber	***Product***	***CFU/ 33cm²***		
		Day 0	***Day 7***	***Day 21***
Chambers 1-4	ceiling tile	0.2	0.0	0.0
	dry wall	0.3	0.0	0.1
	new carpet	1.5	2.5	0.9
Chambers 5-8	ceiling tile	0.1	0.3	0.0
	dry wall	0.0	0.5	0.0
	used carpet	19.1	7.4	3.0
Chambers 9-12	ceiling tile	0.8	1.0	0.1
	dry wall	0.0	0.9	0.1
	new tile	12.0	8.0	8.1
Chambers 13-16	ceiling tile	0.3	0.1	0.0
	dry wall	0.1	0.1	0.0
	used tile	30.9	14.5	16.4

Phase 2 produced surprising results: Very limited grow was measured at high humidity levels (80%) for 21 day test period.

At day 21, a decision was made to keep the chambers active for additional weeks. On 5th week of the 80% RH test regime, visible mold was observed on dirty carpet and dirty floor tiles. On 6th week, day 48 (June 15, 2002) of exposure to unusually high humidity a visual observation of mold was conducted and recorded for all 16 chambers. The exposure conditions at the time of observation were 82^0 F and 78% RH. Photographs were taken of mold growth on carpet and other materials in support of these observations.

Table 4. Phase II Observations of Visible Mold Growth Day 48

Chamber	*Flooring*	*Drywall*	*Ceiling*	*Wood Studs*
Chamber 1 New Carpet	None observed	Possible few	None observed	None observed
Chamber 2 New Carpet	None observed	Possible few	None observed	None observed
Chamber 3 New Carpet	None observed	None observed	None observed	None observed
Chamber 4 New Carpet	None observed	None observed	None observed	None observed
Chamber 5 Dirty Carpet	Significant visible growth	Possible few	None observed	Possible few
Chamber 6 Dirty Carpet	Growth on isolated spill area	Possible few	None observed	Significant visible growth
Chamber 7 Dirty Carpet	Significant visible growth	Possible few	None observed	None observed
Chamber 8 Dirty Carpet	Growth on two isolated soiled areas	Possible few	None observed	Possible few
Chamber 9 New VCT	Significant visible growth	Significant visible growth	None observed	None observed
Chamber 10 New VCT	None observed	None observed	None observed	None observed
Chamber 11 New VCT	Scattered	Possible few	None observed	None observed
Chamber 12 New VCT	Scattered	Possible few	None observed	None observed
Chamber 13 Old VCT	Growth in one area	Growth in one area	None observed	None observed
Chamber 14 Old VCT	Possible few	Possible few	None observed	None observed
Chamber 15 Old VCT	Significant visible growth	Possible few	None observed	None observed
Chamber 16 Old VCT	Significant visible growth	Scattered	None observed	None observed

***Observations made and noted by Carey Mitchell June 15, 2001.**

Table 5. Mean Total CFU Isolated at 80% RH

Chamber	*Product*	*CFU/ 33cm²*		
		Day 0	***Day 7***	***Day 21***
Chamber 1-4	ceiling tile	2.1	1.0	0.5
	drywall	0.4	1.7	1.6
	new carpet	20.9	20.4	8.5
Chamber 5-8	ceiling tile	1.8	1.1	0.1
	drywall	1.6	0.6	1.2
	used carpet	17.9	12.8	14.3
Chamber 9-12	ceiling tile	1.2	0.3	0.2
	drywall	0.4	1.5	0.3
	new tile	7.6	2.6	4.1
Chamber 13-16	ceiling tile	0.8	0.4	0.2
	drywall	1.7	0.8	0.4
	used tile	8.2	3.3	1.7

In addition to visible observation, swab samples were taken and sent to RTI for evaluation. These data confirmed the visual observation that growth had occurred. However, contact plate samples and swab samples cannot be directly compared. Each swab was collected from a site that would equal 1 CFU on a contact plate, so numbers multiple orders of magnitude would be expected.

Table 6. Swab Data - Day 48 Verifying Visible Mold Growth

Chamber	*Product*	*CFU/33cm²*
Chamber 1	Ceiling tile	0
Chamber 1	Wall	0
Chamber 5	Wall	15
Chamber 5	Used carpet	2.1×10^6
Chamber 6	Wall	0
Chamber 6	Used carpet	1.8×10^6
Chamber 7	Wall	0
Chamber 7	Used carpet	1.5×10^6
Chamber 7	Used carpet	1.3×10^6
Chamber 8	Wall	1.0×10^6
Chamber 8	Used carpet	1.9×10^6
Chamber 9	New tile	7.7×10^4
Chamber 16	Used tile	15

Moisture meter measurements on day 48 were recorded as follows. Dirty carpet appeared to absorb more moisture than the clean new carpet. Carpet construction being equal, dirt is hydroscopic and is the most probable the cause of additional moisture retention.

Table 7. Phase II Moisture Levels in Materials Day 48 and Day 63

Chamber	*Moisture Drywall Day 48*	*Moisture Drywall Day 63*	*Moisture Carpet/VCT Day 48*	*Moisture Carpet/VCT Day 63*	*Moisture Wood Day 48*	*Moisture Wood Day 63*
1	15	15	13	12	12	15
2	15	15	12	12	15	15
3	15	15	12	13	12	15
4	15	15	14	12	14	15
5	16	14	13	20	12	15
6	16	15	13	15	12	12
7	16	15	13	15	12	12
8	16	15	13	13	12	18
9	15	15	7	7	12	16
10	15	15	8	13	12	14
11	15	15	8	14	12	16
12	15	15	8	14	10	15
13	15	15	8	N	11	18
14	15	15	7	N	14	14
15	14	14	7	14	11	16
16	14	14	7	14	10	12

On day 48, one-half liter (500 ml) of water was distributed across all materials in the test chambers. These materials were exposed to a temperature of 80°F and relative of humidity of 80% for another 14 days.

On day 63, (July 2, 2001), a visual inspection was made of all 16 chambers. There was no apparent contribution of the 500 ml watering to the growth of mold on flooring surfaces beyond what was previously observed. The surface that appeared to exhibit the most mold growth in virtually every chamber after exposed to water 14 days earlier was the wood framing holding the drywall.

Table 8. Observations of Visible Mold Growth Day 63

Chamber and Flooring Type	*Observation*
Chambers 1-4 New carpet	Mold visible only of surfaces previously stamped with sampling plates.
Chamber 5-8 Dirty carpet	Mold visible only on dirt and spills on carpet.
Chamber 9-12 New VCT	Mold visible only on surfaces previously stamped with sampling plates.
Chambers 13-16 Dirty VCT	Mold visible on studs and on dirty floor.

***Observations made and noted by DR Michael Berry July 2, 2001**

On day 63, a final sampling was conducted as following for each of the 16 test chambers.

Table 9. Sampling Regime for Each of 16 Chambers on Day 63

Conditions 63days	***Floor***	***Ceiling***	***Drywall***	***Wood Studs***	***Total Samples***
Temp = 80°F Humidity=80%	2	1	2	2	112

Moisture levels of materials were measured on Day 63 (July 2, 2001). (Note: All materials in the test chambers were saturated with 500mg water 14 days earlier.) The results are noteworthy and are listed in Table 7. Again, dirty carpet appeared to retain higher levels of moisture and mold growth. But important for this study is the large amount of water retained by wood,

Table 10. Comparison of Mean Total CFU Phase II (80°F/80%)

Chambers	**Product**	**CFU/ 33cm²**			
		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

The results of Phase 1 and Phase 2 strongly suggested that if materials are clean and free of dirt and nutrient, significant mold growth would not occur at any humidity level. To examine this hypothesis, a four-month follow on study was designed which would involve the cleaning of flooring materials and an 8 week exposure to the same Phase 1 and Phase 2 temperature and humidity levels.

PHASE III

On July 2, all 8 chambers with carpet were removed from test area. Carpet was cleaned using a truck mounted cleaning system. The principle of maximum extraction and minimum residue was applied throughout.

The cleaning procedure was as follows:
All eight (8) carpet samples were cleaned with clean hot water alone. Temperature of the water was estimated at 170°-190° 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. 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 carpets were cleaned with hot clear water and extracted for 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 cleaning solution (surfactant). The solution was allowed to dwell for 5 minutes and agitated with carpet rake. All residues were extracted from the carpet with clean hot water.

Extensive photographs were taken of the cleaning process. It was appearant that the aged dirty carpet had not been previously cleaned.

On July 16, all 16 chambers were reassembled and exposed to 65% RH at 80°F.

The first sampling of Phase III was conducted on August 14, 2001. Sampling data from HydroLab indicated all products were highly contaminated with *Aspergillus glaucus* (*Asp.g.)*. A uniform spore deposition (*Asp.g.*) was detected on all the materials sampled, This particular species of mold suggests that that the most likely source of spore was from mold growth on wet wood framing material (Gravesen S. *et al.* 1994). A decision was made at that time readjust the HydroLab project.

The chambers were observed for an additional month. On September 19, 2001, we sampled flooring materials in 16 chambers. These samples tend to suggest that culturable ***Asp.g*** spore was being deposited on test materials (ceiling tiles, drywall, flooring). There was no indication of active mold growth on any of the test materials. Of note, sampling on September 19, 2001 collected about twice as many culturable spores off of VCT than off of carpet.

Table 11. 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

PHASE IV

After the sampling on September 19, 2001, we disassembled, cleaned and dried the test area. We discarded all walls, ceiling tiles, test area plastic. We kept all 16 flooring samples carpet/VCT, cleaned these, and exposed just these 16 floor surfaces at 80%/80°F for two months in a newly established test area.

Baseline sampling of the 16 flooring samples was conducted on September 29, 2001. The results of that sampling indicated that the samples had been exposed to an outdoor source of fungal spore.

At the time the flooring samples were cleaned and exposed to outdoor air on September 19, 2001, an adjacent bean field was harvested. This was the most likely source of *cladosporium* and *epicoccum* found on all 16 flooring samples (Gravesen S. *et al.* 1994). The amount of detected fungi was direct proportion to the order in which sample tables were placed in the test area and the amount of time each was exposed to outside air and natural deposition. This natural event is typical of what indoor furnishing experience when exposed to outdoor air.

Table 12. 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°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

We used this situation and observation as an opportunity to test the hypothesis that routine vacuuming would remove spore and manage mold growth.

All flooring was exposed to an 80F^{o}/80% climate form September 19, 2001 to November 30, 2001

All 16 floor surfaces vacuumed in a typical four pass non aggressive manner on October 10 and October 20.

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.

Table 12. 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

CONCLUSIONS

The three week Phase 1 exposure (80°F/65%) verified the suggestions of the technical literature related to humidity levels and mold growth. Mold was found not to grow at 65 % humidly levels on any of the test materials within the 3 weeks of the study.

In Phase 2, mold growth did not occur at 80°F/80% RH exposure level within the 3 weeks of the study as was expected. Visible mold was found by the by the 5th week. It was very appeared that mold growth occurred only in/on the dirt on carpet and VCT and naturally organic materials such as bare wood. Mold was not seen to grow on clean nylon.

Conductivity moisture readings of 14 and higher were associated with mold growth on all materials. Moisture meters vary in their readings, but the important finding is the relation of mold growth with higher moisture content readings.

The essential key to mold grow is dirt or organic nutrient and elevated moisture content in materials. Dirt in carpet is hydroscopic and absorbs moisture. Dirt spots on carpet high were found to have nearly 10-15% higher moisture levels than clean portions of the nylon carpet. Mold was found to grow only on the dirty portion of the carpet.

Mold growth was observed to occur on the dirty portion of VCT.

Phase III demonstrated that it is not possible to cultivate large numbers of mold spores on clean surfaces (carpet and VCT). When clean surfaces that contained large numbers of spores were exposed to elevated temperature and humidity levels (80oF/80%) for over two months, mold growth was not found to occur. The absence of an organic nutrient even in the presence of moisture makes mold growth impossible.

Phase IV demonstrated that mold spore is naturally deposited on all surfaces. It was clearly demonstrated in Phase IV that vacuuming carpet surfaces is highly effective in reducing and managing the levels of culturable mold spore. Phase IV also reinforced the finding of Phase III, that even at elevated temperature and humidity levels (80°F/80%) for a period of two months, clean carpet does not support mold growth.

Clean/new carpet does not support mold growth even at elevated humidity levels. Basic conclusion for this project is that for any material: Dirt + Water (High Humidity) = Mold. The obvious management solution for mold is to keep all materials dry or at least clean.

Reference List

ACGIH: 1999, Bioaerosols, American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

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