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IAQ Study of Schools in Relation to Flooring Types and Cleaning Processes

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SUMMARY
Indoor air quality studies in schools related to flooring types and cleaning effectiveness was conducted over a 2 year period in elementary schools with both carpet and resilient flooring in individual classroom settings. Separate classrooms were chosen for study from each school- one with carpet and one with resilient flooring. School 1 did not have a defined routine maintenance plan other than nightly sweeping of the hard surface floors and an "on call" deep cleaning as needed for spills or obvious soiling. The six year old carpet in School 1 has been "deep" cleaned once 4 years prior to the study. School 2 was a two year old school with a documented "green" cleaning plan with nightly microfiber mopping of the hard surface floors and vacuuming of the carpet. Low volatile organic compound (VOC) cleaning chemicals were used on building surfaces including the flooring. The carpet had been "deep" cleaned on an annual basis. For this study, comprehensive indoor air quality measurements were made periodically over a two year period (4 times) in the selected classrooms of both schools. Measurements included volatile organic compounds VOCs) including formaldehyde; airborne and dust levels of environmental fungi; airborne and dust levels of animal and insect allergens; and respirable particles. Each school continued its routine cleaning maintenance with the addition of a thorough or "deep" cleaning of the flooring every other test period. In these cases, IAQ measurements were made immediately before, 12 hours and 24 hours following cleaning. Overall the data showed that particulate and microbiological contaminants were significantly higher in the school with limited cleaning procedures; deep cleaning of the flooring was effective in removing over 70% of the microbiological allergens in carpet and over 30% from the hard surface flooring; and that cleaning procedures related to resilient flooring resulted in extended VOC exposure following thorough cleaning. The data trend over time showed significantly less indoor air and settled dust pollution in the school with routine "green" cleaning procedures than the school with limited cleaning.

IMPLICATIONS

Protecting indoor air quality in schools and the health of children is a high national priority. This study will demonstrate the impact of flooring types on IAQ and how proper cleaning and maintenance can improve indoor air quality and help protect children from exposure to harmful contaminants including VOCs, dust and allergens.

KEYWORDS

VOCs, allergens, flooring, schools

INTRODUCTION

According to the US Environmental Protection Agency (USEPA), 20 percent of the US population (55 million people) spends a significant amount of time each day in more than 120,000 public and private schools. As a part of its review and assessment of the health and productivity benefits of green schools, the National Research Council found "a robust body of evidence indicating that the health of children and adults can be affected by air quality in a school," and "a growing body of evidence [suggesting] that teacher productivity and student learning, as measured by absenteeism, may be affected by indoor air quality as well" (National Research Council 2006). The California Air Resources Board (CARB) reached a similar conclusion in its report to the California Legislature on the quality of indoor air in that state (CARB 2005). Poor IAQ in schools can place millions of adults and children at risk for health problems, such as coughing, eye irritation, headaches, asthma, allergies, and more chronic diseases. Among those most at risk are the more than 6 million students who have asthma. Asthma can be life-threatening if not properly managed, and is the leading cause of school absenteeism and hospitalizations in children under the age of 15. Asthma accounts for an estimated 14 million lost school days and $16 billion in annual health care expenditures for both children and adults (AAAAI 2005).

Indoor air quality in schools is affected by a myriad of factors including ventilation, cleanliness, and sources and availability of pollutants. Pollutants that include dust particles, VOCs, mold, and biological allergens can originate from construction materials; furnishings; daily processes such as cleaning and photocopying; pets; animals; pests; and secondarily, by chronic presence of soil and moisture leading to the proliferation of dust mites and mold. This study evaluates the impact of flooring and its cleaning processes on indoor air quality and also measures the effectiveness of cleaning in achieving a long term reduction in pollutant load within a school environment.

METHODS

Two elementary schools were chosen for study in Atlanta, Georgia and testing was conducted over a two year period for both schools. Periodic testing was conducted within the same week at both schools to control temporal differences. Deep cleaning was conducted every other test period using a commercial hot water extraction system for carpet and low impact system for resilient flooring. Separate classrooms with carpet and resilient flooring were chosen for study serving kindergarten aged children. Control rooms, where deep cleaning was not performed, were used to collect samples so that comparisons could be made measurements obtained in the classrooms with deep cleaning.

Analytical and biological measurements were made using standard techniques applicable for indoor environment measurement studies. VOCs were measured following a mass spectrometric method according to EPA method TO-17 (1999); aldehydes were measured using a high performance liquid chromatographic method according to ASTM D 5197 (2007); culturable fungi in air were collected on a plate impactor with malt agar extract (MEA) followed by incubation and fungi enumeration to the species level; settled dust fungi were collected using vacuum collection on a filter cassette followed by direct or dilution plating on MEA with incubation and fungi enumeration to the species level; and allergens were quantified with micro titer plate based enzyme immunoassay technique (ELISA) using allergen specified monoclonal antibodies to detect bound allergens. All microbiological methods followed the guidance of AIHA's Field Guide for the Determination of Biological Contaminants in Environmental Samples, 2^{nd} edition (2005). Airborne particles less than 10 um in diameter were measured using real time light scattering aerosol monitors.

RESULTS

VOCs

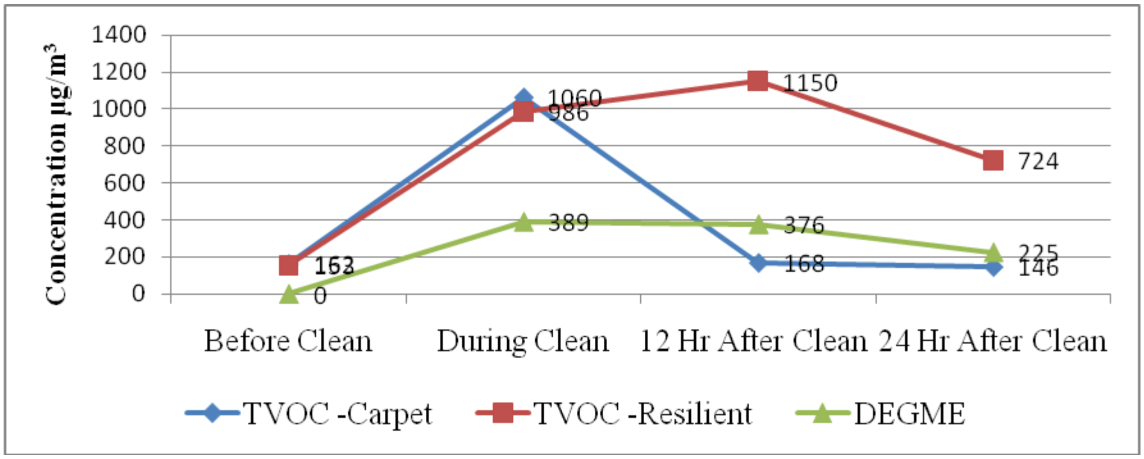
Numerous low levels of VOCs were found in the school environments. A summary of the average TVOC values and formaldehyde levels in ug/m^3 as measured across the 2 year testing period are presented in Table 1. Airborne chemical levels were similar among both schools and within each type of floored classroom. Measured indoor TVOC was 8-25 times higher than the outdoor level and formaldehyde ranged from 2-4 times higher. Floor cleaning processes increased airborne levels of VOCs as demonstrated in Figure 1. For carpet, TVOC levels increased during the actual cleaning process but rapidly decreased to preclean ranges within 12 hours of the cleaning process. Primary VOCs associated with carpet cleaning included limonene, 2- butoxyethanol, and tetrachloroethylene. There was a small residual level of 2 -butoxyethanol 12 hours after cleaning, but it dissipated within 24 hours. For resilient flooring, VOC levels increased during cleaning and remained elevated 12 hours after cleaning as demonstrated in Figure 1 with TVOC and the primary VOC, diethylene glycol monoethyl ether (DEGME). These chemicals were still measured in significant levels within 24 hours after cleaning. Additional primary VOCs associated with the resilient floor cleaning included numerous glycols including 2-butoxyethanol and 2-methoxypropoxyethanol.

Table 1.

Average TVOC & Formaldehyde Levels		
	TVOC, µg/m^3	Formaldehyde, µg/m^3
Carpet –School 1	144	26
Carpet –School 2	115	16

Resilient –School 1	356	31
Resilient –School 2	187	32

Figure 1.



Allergens

There were no measurable levels of airborne allergens in the carpet classrooms except for one measurement of cat allergen during one sampling period. In contrast, airborne cat allergen was found during all 4 sampling periods in the resilient classroom of School 1 with an average value of 0.8 ng/m^3. There were no measured airborne levels of mite, cockroach, rate or mouse allergens in any locations. Cleaning of the resilient flooring resulted in an average 42% reduction in airborne cat allergen levels, as measured 12 hours following cleaning.

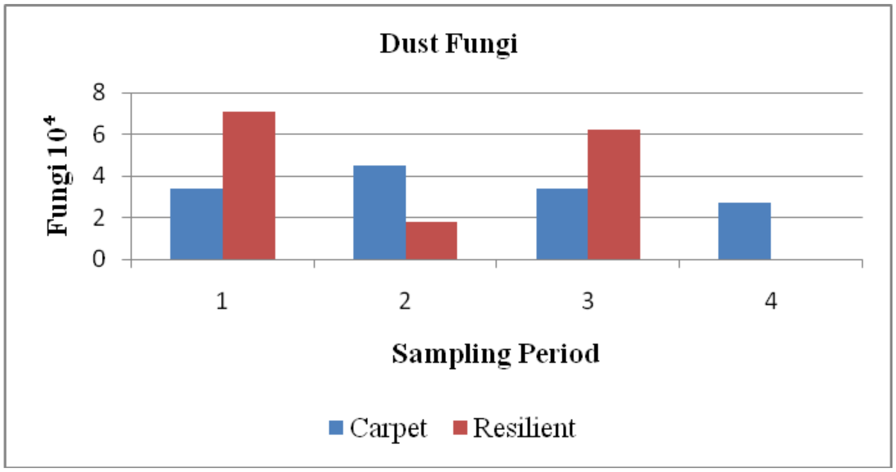
There were additional measurements of allergens in the settled dust, as extracted from the flooring materials. In particular, numerous dust allergens found in School 1 where dust mite, cat, dog and cockroach allergens were measured during the first sampling period. Primary allergens in the carpet dust included dust mite and dog allergens whereas the resilient flooring dust primarily contained cockroach, mouse, and cat allergens. School 2 presented measured levels of cat and dog allergen but at significantly lower levels. Carpet cleaning processes resulted in an average 72% reduction in dust allergen levels. Resilient flooring dust in School 1 with measurable levels of cat, dog, mouse and cockroach allergens, and floor showed an average 32% reduction following cleaning.

Mold (Fungi)

Airborne fungi levels were unremarkable in relation to outdoor measurements, dominated by *Cladosporium* and non sporulating fungi. Levels were higher in School 1 ranging from 100-3270 CFU/m^3 for the carpet floor classroom and 20-190 CFU/m^3 for the resilient floor classroom. School 2 had lower measured levels that were similar in both the carpet and resilient classrooms with levels ranging from 20-60 CFU/m3. Airborne levels in School 1 showed an average 76% decrease in airborne fungi levels following cleaning.

Fungi in extractable floor dust from School 1 are compared in Figure 2 between the different classrooms. Overall levels were similar with dominance of *Cladosporium* with a greater presence of *Aureobasidium* and *Rhodotorula* in the resilient floor dust. There was also an indication of *Penicillium* amplification in the resilient dust. Deep cleaning resulted in a 69% and 84% reduction in dust fungi for the resilient and carpet flooring, respectively.

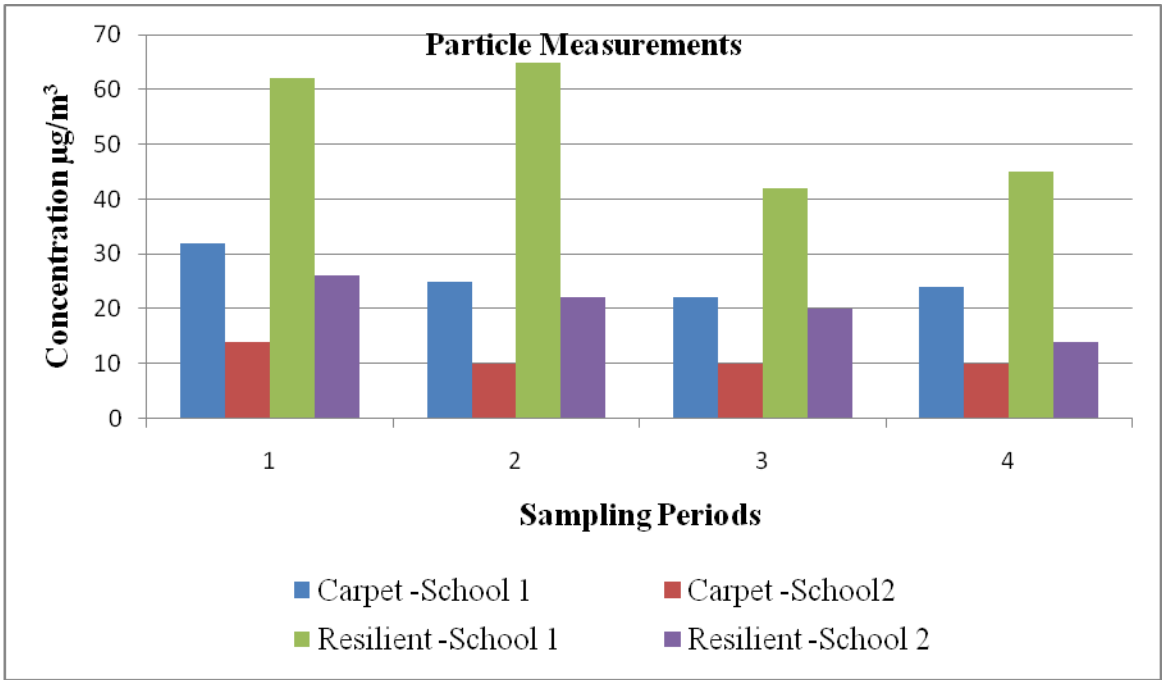
Figure 2.



Respirable Particles (less than 10 m^3)

Figure 3 demonstrates the respirable particle levels across the 4 sampling periods for each of the classroom environments. In all cases, data indicate higher particle levels among the resilient surfaced rooms in comparison to carpet. There is also a trend downward in particle levels overall with time.

Figure 3.



DISCUSSION

Research has shown a clear link between indoor air quality in schools and educational performance, productivity, sense of well – being and occupant health. As a result, successful management of a school environment is a critical requirement and ultimate investment. This management covers the life cycle of a school from its design and construction to everyday operation and maintenance. Indoor air quality is affected by numerous factors, but one of the key management tools is the use and selection of low emitting products, and obtaining assurance that these products will contribute to overall good indoor environmental quality.

This study serves to present environmental pollutant data from schools in relation to the use of two commonly used flooring materials, carpet and resilient flooring. The data explores the impact of these materials on classroom IAQ, and also addresses an evaluation of their maintenance processes on IAQ. The information provided can assist designers and facility managers in appropriately choosing or specifying materials for use. It also provides data demonstrating the importance of maintenance procedures in keeping flooring free of unnecessary contaminants, while assuring that the maintenance procedures themselves do not contribute to indoor pollution.

CONCLUSIONS

Overall data showed that routine cleaning is important in controlling indoor pollutants associated with flooring. Particulate and microbiological contaminants were significantly higher in the school with limited cleaning procedures, regardless of the flooring type. Deep cleaning of the flooring was effective in removing over 70 % of the microbiological allergens in carpet and over 30% from the resilient flooring. Data also showed that VOCs associated with the cleaning processes could affect IAQ. Cleaning VOCs associated with resilient flooring process demonstrated a potential long term exposure situation for classroom occupants.

Relative to specific indoor air pollutants, cat and dog allergens were the most frequently found floor dust allergens with some limited occurrence of dust mite, cockroach and mouse allergens. These allergens in general were not found to be airborne with the exception of cat allergen as found associated with resilient floor covering. The presence of airborne mold associated with flooring was unremarkable and floor dust mold was generally dominated by outdoor contributions. There was an indication of increased yeast contamination related to resilient flooring which could be associated with the re- use of certain maintenance tools.

The data trend over time showed significantly less indoor air and settled dust pollution in the school with routine "green" cleaning procedures than the school with limited cleaning.

REFERENCES

K., H., Patricia A., and J. D. *Field Guide for the Determination of Biological Contaminants in Environmental Samples*. American Industrial Hygiene Assn, 2005. Print.

American Academy of Allergy, Asthma and Immunology. Asthma Statistics Media Kit. Available online at **www.aaaai.org/media/resources/media_kit/asthma_statistics.stm**. Accessed May 19, 2005.

ASTM. 2009. *D5197, Test Method for Determination of Formaldehyde and Other Carbonyl Compounds in Air (Active Sampler Methodology).* West Conshohocken, PA: ASTM.

CARB. Draft Report to the California Legislature: Indoor Air Pollution in California. California Air Resources Board. Sacramento, California. February 2005.

EPA. 1999. *TO-17, Determination of Volatile Organic Compounds in Ambient Air Using Active Sampling onto Sorbent Tubes*. Cincinnati: U.S. Environmental Protection Agency.

National Research Council of the National Academies. Review and Assessment of the Health and Productivity Benefits of Green Schools: An Interim Report. The National Academies Press. Washington, D.C. 2006. Available online at **http://newton.nap.edu/catalog/11574.html**.