

Carpet, Asthma and Allergies – Myth or Reality

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Summary: The relationship between carpet, asthma and allergies has been the subject of numerous scientific and medical investigations. The literature on this topic has been carefully reviewed. The initial focus was the etiology of asthma and allergies. The proximate cause, or why individuals develop asthma or allergies, is not known. However, triggers for asthma and allergies are known and focus on irritants (e.g., VOC) and allergens (e.g., dust mites and other sources of biocontaminants). Carpet has not been implicated as a trigger for asthma or allergies. Carpet emits VOCs for very short durations and at very low levels. Levels of VOCs from carpet have a very low probability of acting as asthma triggers. While carpet may have a higher burden of biocontaminants, airborne levels of these biocontaminants are similar or lower than over hard flooring surfaces according to most studies. Carpet appears to trap or sequester biocontaminants taking them out of the atmosphere. Based on the low level and short duration of carpet VOC emissions and sequestering nature of carpet with respect to biocontaminants, one would predict that carpet would not have an adverse health impact compared to hard floor surfaces. Indeed, the significant literature on carpet and asthma or allergies confirms that children and adults inhabiting carpet surface rooms do not have an increased incidence of asthma or allergies. The incidence of asthma continues to increase while the use of carpet has decreased significantly. In conclusion, based on the available science, carpet does not cause asthma or allergies and does not increase the incidence or severity of asthma or allergies symptoms. In fact with respect to asthma and allergies, multiple studies have reported fewer allergy and asthma symptoms associated with carpet.

Introduction and Background: In the past few years, the public media in the U.S. and Europe have presented intermittent bursts of unfavorable and negative commentary regarding carpet. As such, carpet is sometimes perceived by the public as a potential contributor and/or cause of asthma and allergies. This anti-carpet message has permeated into the educational and health care communities. Health professionals, some uninformed and others not understanding and/or aware of current research, have recommended that asthma and allergy patients remove carpet from their homes. Further, school districts have been advised by anti-carpet advocates and so-called “mold experts” to remove carpet at the cost of millions of dollars. Historically, carpet has been viewed as a sink acting as a secondary source of exposures. However, this perception is inconsistent with current research. It is not surprising in view of misinformation that decisions on floor coverings in homes, schools, and places of business are often based on a false set of assumptions. Voices of science and reason are often overwhelmed by misguided public sentiment.

There is, however, meaningful medical and scientific literature regarding carpet, asthma, and allergies. The intent of this manuscript is to review the literature and present major conclusions regarding the potential relationship, if any, between carpet, asthma, and allergies. Extensive scientific, medical and toxicological literature has been reviewed

and the scientific conclusions supported by that literature have been reached using a weight of evidence approach.

Asthma and Allergies: Prior to a discussion of carpet, asthma, and allergies, it is *critical* to define those medical conditions that we refer to as asthma and allergies.

Unfortunately, many asthma symptoms are shared by other conditions and, as a result, the public perception of asthma and statements by individuals claiming asthma are often wrong. A proper and medically sound asthma diagnosis follows pulmonary function testing by a suitably trained physician and a differential diagnosis ruling out other potential and similar medical conditions (e.g., chronic obstructive pulmonary disease). Claims of “having asthma” in the absence of medical diagnosis cannot be accepted as medically correct. Thus, those studies in the literature based on perceived breathing difficulties or selfreporting of asthma in the absence of a proper asthma diagnosis are suspect at best and not scientifically sound.

Asthma has moved to center stage as a public health problem in the last 35 years.^{Ref. 1} The prevalence of asthma has apparently increased dramatically.^{Ref. 2} Asthma is now recognized as a major cause of disability, medical expenses, and preventable death.^{Ref. 3} Asthma is a worldwide problem with an estimated 300 million individuals affected.^{Ref. 4, 5,}

⁶ Despite hundreds of reports on the prevalence of asthma in widely differing populations, the lack of a precise and universally accepted definition of asthma makes reliable comparison of reported prevalence in different parts of the world problematic.^{Ref. 6}

⁶ However, based on the application of standardized methods to measure the incidence of asthma and wheezing in children and adults, the global prevalence appears to range from 1% to 18% of the population in different countries.^{Ref. 5, 6, 7} Wales, New Zealand, and Ireland are the three countries with the highest rate of asthma (15%-18%). Asthma rates in the US, Belgium, and Denmark are 11%, 6-7%, and 3%, respectively. The incidence of asthma ranges over five-fold in these “Western” countries.

In the U.S., data from the National Health Interview Survey (NHIS) showed that the overall prevalence of asthma increased from 3.1% in 1980 to 5.5% in 1996.^{Ref. 8} In 1997, the definition of asthma changed according to NHIS from self reports of asthma to physical diagnosis by a physician and symptoms within the last 12 months. Change in diagnostic and reporting criteria underscore the difficulty of providing accurate information of changes in the incidence of asthma. The increase in asthma is not limited to countries in the West. For example, the prevalence of asthma increased in Taiwanese children from 1.3% in 1974 to 5.8% in 1985.^{Ref. 9} In general, the rate of asthma increase has been much greater for children than adults suggesting that the rise in asthma prevalence may reflect an early window of opportunity for susceptible individuals.^{Ref. 10}

Although physicians seem comfortable with their ability to diagnose asthma as a clinical disease, agreement on a definition has proven elusive.^{Ref. 1} Asthma has been described more than defined. The term asthma is derived from the ancient Greek word for “panting.” The National Heart, Lung, and Blood Institute has defined asthma as follows in their 2007 “Global Initiative for Asthma” report update.^{Ref. 6}

“Asthma is a disorder defined by its clinical, physiological, and pathological characteristics. The predominant feature of the clinical history is episodic shortness of breath, particularly at night, often accompanied by cough. Wheezing appreciated by auscultation of the chest is the most common physical finding. The main physiological feature of asthma is the episodic airway obstruction characterized by expiratory airflow limitation. The dominant pathological feature is airway inflammation, sometimes associated with airway structural changes. Asthma is a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role. The chronic inflammation is associated with airway hyperresponsiveness that leads to recurrent episodes of wheezing, breathlessness, chest tightness, and coughing, particularly at night or in the early morning. These episodes are usually associated with widespread, but variable, airflow obstruction within the lung that is often reversible either spontaneously or with treatment.”

What is quite clear in the medical literature is that the cause of asthma is not known. According to the U.S. National Heart, Lung, and Blood Institute website, the exact cause of asthma is not fully understood at this time. This point of view is shared by virtually all major medical and health associations. What is clear, however, is that certain triggers may set off or precipitate an asthma attack in susceptible individuals. Triggers most widely thought to precipitate an asthma attack include the following:

- Infections such as colds and the flu;
- Irritants such as dust, cigarette smoke, fumes;
- Chemicals found in the workplace – this is referred to as occupational asthma;
- Allergies to pollen, medicines, animals, dander, house dust mites, mold, cockroaches, or certain foods;
- Exercise – especially in cold, dry air;
- Emotions – laughing or crying very hard can trigger symptoms as can stress.

Critical concepts to understanding the remainder of this report are recognizing the difference between triggers that cause asthma episodes and that the underlying cause of asthma is unknown.

As noted above, it is *critical* to define those conditions that we refer to as asthma and allergies. This concept applies no less for allergies than for asthma. The public perception of allergies and statements by individuals claiming allergies are often wrong. It is essential for a proper and medically sound allergy diagnosis including a differential diagnosis. Claims of “having allergies” in the absence of medical diagnosis cannot be accepted as medically correct. Thus, those studies in the literature based on perceptions or self reporting of allergies in the absence of a proper diagnosis are suspect at best and not scientifically sound.

Understanding allergies requires a brief and simplified course in immunology. An allergic reaction refers to an exaggerated reaction by the immune system in response to bodily contact with certain foreign substances. The reaction is exaggerated in that the foreign substance (allergen) is usually seen by the body as harmless and no response occurs in non-allergic people. An allergic person's immune system recognizes the substance as foreign and the immune system is turned on. The most common allergic reactions include hay fever, allergic eyes (conjunctivitis), allergic eczema (hives), and allergic shock (anaphylaxis). Allergic reactions can also be considered from the standpoint of time. In other words, those allergic reactions that are immediate contrast with those that are delayed. An immediate allergic reaction is referred to as anaphylaxis. Anaphylaxis has immediate medical consequences potentially causing breathing difficulties and shock. Common causative agents include foods, especially peanut butter in children and insect bites. Importantly, anaphylaxis is **NOT** an immediate allergic reaction associated with carpet. Delayed allergic reactions are more familiar. Typically, this form of allergic reaction is one of the top ten reasons for patient visits to primary care offices. Contact dermatitis (hives) is produced following cutaneous (skin) contact with a specific allergen to which the individual has previously developed a specific sensitivity. Perhaps the best recognized example of contact dermatitis is poison ivy, oak, or sumac. The active allergen in poison ivy and oak is urushiol. More than 79% of the US population is allergic to urushiol.

When carpet has been discussed in relationship to allergic reactions, it is in the context of allergic rhinitis. In the past, carpet has been thought of as a secondary source wherein the carpet acts as a sink accumulating the allergen. Whether the so-called sink contributes to or traps and removes allergens from the atmosphere will be discussed below. Synonyms for allergic rhinitis include seasonal allergies, seasonal rhinitis, and hay fever. Allergic rhinitis is characterized by inflammation of the nasal passages with sneezing and a runny nose, also known as rhinorrhea. Additional symptoms include nasal itching, irritated eyes, and increased tearing. Allergic rhinitis can be seasonal or perennial. This latter form of rhinitis is usually caused by house dust mites, animal dander, cockroaches, and some molds (e.g., *Alternaria* and *Cladosporium*). Allergic rhinitis is quite prevalent in children and adults with an incidence of 10 or 15 in 100,000, respectively. Clinical presentation includes inflamed nasal membranes, paroxysmal sneezing, nasal congestion, nasal itching, and rhinorrhea. Diagnosis can be confirmed by a skin prick test or blood test known as the radioallergosorbent test or RAST.

Asthma triggers and/or allergens can be subdivided into different categories for the purposes of discussing the potential relationship between carpet, asthma, and allergies. Two potentially important categories are chemical irritants (e.g., tobacco smoke, fumes, and dust) and biopollutants such as pollen, animals, dander, house dust mites, mold, and cockroaches.

The first section of this manuscript provided a basic understanding of asthma and allergies, their etiology and prevalence. Having reached this important understanding, a discussion of the medical and scientific literature characterizing the relationship between asthma, allergies, and carpet is summarized and major conclusions provided.

Exposure to Volatile Organic Compounds (VOCs), Dusts and Allergens: Risk of harm to a given chemical substance or a so-called biopollutant is a function of exposure and the inherent health hazard of the substance/biopollutant under study. This risk paradigm is standard in the world of risk assessment and has been accepted by U.S. (EPA, FDA, CPSC) and international authorities (European Medicines Agency, European Chemicals Bureau, United Nations World Health Organization). One logical question that evolves from this risk paradigm as it applies to carpet is how does carpet affect exposure to those substances that might have an effect on asthma or allergies?

In the first case, chemicals, namely volatile organic compounds (VOC) potentially emitted from carpet are considered herein. Chemical irritants are thought to be asthma triggers, although not related to allergies. What are the levels of VOC known to be emitted from carpet and how do these emissions affect indoor air quality?

Environ studied the safety of known components of and emissions from new carpet.^{Ref. 11} Environ reviewed scientific databases concerning potentially adverse health effects of VOC and emissions from new carpet. Environ employed very conservative exposure scenario assumptions including carpet life of nine years and occupants remaining in the home 24 hours/day. Environ found no human health concerns with components of or emissions from carpet. The Environ study went well beyond the focus of carpet related asthma and allergies. However, Environ examined VOC emissions from carpet and compared emissions to recognized human health exposure standards. Levels of VOC in the air from new carpet are short-lived as off-gassing occurs over a very short duration of time relative to the nine-year carpet life. Levels of VOC from carpet off-gassing are too low to elicit irritant responses and, hence, too low to act as triggers for asthma. In addition, while carpet off-gassing of VOCs are intermittent and short-lived, these same VOCs are used widely in other consumer products and in food-contact applications. VOC exposures from these non-carpet applications are likely to be higher and much longer lasting than from new carpet.

Rodney Dietert and Allen Hedge contributed an important paper to the carpet and VOC literature.^{Ref. 12} They compared emissions data from several studies and described the dominant VOC found in those emissions.^{Ref. 13, 14, 15, 16} Compounds occurring most frequently from SB latex-backed carpet included styrene, 4-phenylcyclohexene, and 4-vinylcyclohexene. The study authors stated the following with respect to VOC emissions. “Depending on the type of product, a new carpet initially is likely to emit between 3 and 400 VOCs, with most samples emitting ten or fewer VOCs. Most of the VOCs emanating from carpet are present in very small or trace quantities under normal climate conditions. After 7 d (days), especially with additional ventilation, emissions of most VOCs will have fallen below detectable levels. All of the analyses reviewed suggest that emissions from new carpet are insufficient by up to three orders of magnitude to pose any significant health risk.”

Many years ago, the Carpet and Rug Institute (CRI) identified the importance of VOC emissions from carpet and rugs and the potential for health impacts.^{Ref. 17} Under the auspices of CRI, Air Quality Sciences evaluated carpet emissions from 14 VOCs.

According to data generated, VOC emissions decrease with time following new carpet installation. Half-life values calculated are generally in the 1-2 day range. Maximum residential and commercial VOC exposures (carpet used in residences and offices) have been calculated and compared with California Safe Harbor Exposures for the 14 VOC. Maximum residential and commercial VOC exposures ranged between 0.005 to 0.84 µg/day and 0.005 to 0.79 µg/day, respectively. Compared with the California Safe Harbor Exposures for these VOC, the margin of safety (concentration of VOC from carpet compared to Safe Harbor concentration) ranged from 6.5 to 15,700. This exposure analysis and comparison with a very conservative safety standard (California Proposition 65) demonstrates the safety of carpet in so far as VOC emissions are concerned.

Thus, VOC emissions from carpet do not present a health hazard when considering the low level and short duration of exposures. **In addition, carpet emissions of VOC are well very low and therefore, the probability of irritants from carpet triggering asthma is extremely low.**

In the second case, biopollutants are considered herein. Biopollutants occur naturally in the outdoor and indoor environment and include pollen, animals, dander, house dust mites, mold, and cockroaches. At least some biopollutants (e.g., animals, dander, house dust mites, and mold) have been linked to allergies and asthma. The critical issue in this discussion is how levels of biopollutants compare in carpeted and non-carpeted indoor environments.

“According to Michael A. Berry, Ph.D., persistent and excessive amounts of moisture which contribute to mold and bacterial growth are almost always major contributors to indoor biopollutant contamination.”^{Ref. 18} Timely moisture management is critical in preventing microorganisms from entering the exponential or stability phase of their life cycle. The importance of moisture management in biopollutant prevention can not be overemphasized. Whatever other environmental management strategies are practiced, in the absence of moisture management, the strategies will have limited effectiveness.

Dr. Berry has continued his investigations into flooring, humidity and mold growth employing high temperature and humidity conditions.^{Ref. 19} Mold growth on carpet and hard wood floors was studied in four phases of highly controlled, elevated temperature and humidity exposures between April and December 2001. Mold growth was evaluated on new and old carpet as well as new and old hardwood floors. In one phase of the investigation, an even distribution of mold spores (*Aspergillus glaucus*) was deposited on carpet after cleaning. After two months of exposure, there was no induction of mold growth on any of the cleaned (old or new) carpet samples. In another phase of Berry’s investigation, mold growth on both carpet (new and old) and hardwood floors (new and old) were compared under high temperature and humidity conditions. Naturally deposited mold 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 hardwood flooring. Dr. Berry states that “the main conclusion of his 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.”

In a study conducted by Research Triangle Institute (RTI) and University of North Carolina (UNC) investigators, two schools in North Carolina were paired as closely as possible.^{Ref. 20} Both schools were from the same school district and situated in rural locations with very similar outdoor environmental conditions. Both schools were first occupied in 1996 and the HVAC systems were quite similar. Both schools appeared well maintained and followed almost identical school district cleaning programs. One school was mostly resilient vinyl tile floors while the other school had 70%-75% carpet floors. The study found that, although the carpet flooring had higher concentrations of biocontaminants than an equal area of tiled floor, airborne contaminants were **higher over tiled floors** than over carpet. This is not a surprising result since one of the properties of carpet is that it keeps dirt from being tracked by a tendency to trap and hold biomaterials that would otherwise be resuspended into the breathing zone.

The RTI/UNC study cited above underscores a critical point regarding biocontaminant levels in carpet and hard flooring surfaces compared with biocontaminant levels in the breathing zone. A comparison of biocontaminant levels in the actual carpet compared with levels on hard flooring surfaces is misleading. Carpet will have a higher biocontaminant burden compared to hard flooring surfaces while actual levels in the air will be lower over carpets. After all, it is the levels of biocontaminants in the air that is the critical exposure component in assessing risk.

Carpet industry data provides further support for the importance of examining airborne levels and not carpet burden of biocontaminants.^{Ref. 21} In 2002, Professional Testing Laboratory was commissioned to study air quality relative to the effect of foot traffic on both commercial carpet and commercial vinyl flooring. Particulate monitors were positioned to continuously measure particle counts during and following 16 minutes of foot traffic. Particulate concentrations above carpet ranged as high as approximately 225 $\mu\text{g}/\text{m}^3$. Particulate concentrations above vinyl floor covering ranged up to approximately 950 $\mu\text{g}/\text{m}^3$. Particulate concentrations over vinyl flooring were about four-fold higher than over carpet. Cleaning of vinyl surfaces with a dust mop caused a greater than two-fold increase over vinyl left undisturbed. Particulate concentrations following use of a dust mop were as high as 2000 $\mu\text{g}/\text{m}^3$.

Alan E. Luedtke, Ph.D. published a comprehensive review of the literature regarding the indoor environment, floor coverings, dusts, and airborne exposures.^{Ref. 22} More specifically, he addressed the composition of soils and dusts, floor loadings, surface loading rates, relationships to re-suspension of dust components and airborne exposures, floor coverings, dust and airborne contaminants. Dr. Leudtke summarized his findings as follows. “The majority of the contaminants that accumulate on smooth floors, in carpet, and on other surfaces appear to be outdoor-sourced. Dusts and soils on flooring were mostly the result of foot traffic. As expected, carpet almost always carried a higher burden of soils, dusts, and trace contaminants per unit area than smooth surfaces. For a large number of contaminants, the levels were similar on a per gram of dust basis.

However, carpet dusts on average tended higher and in a few instances were statistically higher. In a majority of the studies reviewed, the actual differences were not large and rarely exceeded a factor of two. Airborne was the primary route of human exposure for most contaminants of concern. Despite the fact that carpet typically carried higher burdens of contaminants than smooth surfaces, it was extremely rare to find a study that reported a statistically significant contribution for carpet of contaminant to the air. In most of the work covered, indoor concentrations of contaminants were more frequently driven by outdoor conditions or by building occupant activities. There was no correlation between dust mite allergen load in carpet and airborne concentrations. Cat allergen was the only allergen was the only allergen of interest which seemed to show a relationship between surface dust loadings (not just carpet) and air concentrations.”

As noted, not all studies indicate that airborne dust concentrations are lower over carpet. Researchers at Clarkson and Stanford Universities report on elevated personal exposure to particulate matter from activities in a residence.^{Ref. 23} The study authors have characterized a set of human activities that result in resuspension of airborne particulates. Specifically, the authors investigate whether flooring type and vigor of human activity influence particulate matter resuspension. Of the many combinations (flooring types and different human activities) of variables investigated, dancing on a rug resulted in PM_{2.5} concentrations (particles 2.5 micrometers or smaller) over carpet 6-times those produced when dancing on a wood floor.

A study conducted in Norway measured dust content from samples collected in 12 schools with fitted-carpet and linoleum floors.^{Ref. 24} The presence of antigens and allergens was compared using sophisticated analytical techniques. No qualitative differences in allergen contents of dust from both floor types were noted. Similarly, no relationship could be demonstrated between floor-type and allergen concentration under experimental conditions. Furthermore, the study demonstrated that dust from smooth floors and fitted-carpet was relatively free of mite and pollen.

B. A. Cicciarelli and colleagues used Computational Fluid Dynamics (CFD) to model the transient behavior of airborne particles in dwellings with and without carpeted floors to quantify the impact of floor coverings on indoor air quality (IAQ).^{Ref. 25} The study authors concluded that CFD is ideally suited for the careful study of IAQ issues. CFD simulations on a model single room with and without carpet indicate that there is a significant impact of floor covering on airborne particle concentration. According to the computer model, particulate concentrations are lower if the floor is carpeted as opposed to hard surface. The study authors stated that “this difference can be great if the carpet irreversibly traps particles that collide with carpet fibers, due to the much greater surface area available for particle collision in a fibrous carpet compared to that of a hard surface. The impact of carpet on allergic responses can be great both in terms of instantaneous and long term exposure.” In other words, the study authors are claiming that carpets will reduce particulate exposure and reduce adverse health effects as a result.

The weight of evidence supports the conclusion that airborne biocontaminants and dusts over carpet surfaces are generally **lower** in concentration than those same

biocontaminants and dusts in the air over smooth flooring surfaces. In addition, it is known that biocontaminants can trigger asthma and allergic reactions. Based on this knowledge, one would predict that with lower airborne biocontaminant levels, the air in a carpet room would be more healthful or certainly no worse than air in a room with smooth surface flooring. Information in the medical and toxicological literature on this very premise will be discussed next.

The European Commission supported a study entitled “European Community Respiratory Health Survey.” This study examined the association between adult asthma and housing characteristics related to dampness, mold exposures, and house dust mite levels.^{Ref. 26} Data about the present home, heating and ventilation systems, floor coverings, recent water damage, and mold exposure were obtained by means of an interviewer-led questionnaire. The associations between these environmental factors and asthma, as defined on the basis of symptoms in the last year and bronchial responsiveness (pulmonary function testing in the presence of a methacholine challenge) were evaluated in 38 study centers. This study fulfills the important criteria of medically validated asthma diagnosis. The study authors specifically investigated the relationships between carpet and asthma. Carpet constitutes an important predictor of house dust mite allergen levels in homes.^{Ref. 27} In addition, dust from carpet (textile floor coverings) contains more microbial contaminants compared with dust from hard floors.^{Ref. 28} A negative association was reported between textile flooring and asthma. The lack of a relationship between the presence of bedroom carpet and asthma seemed apparent in almost all study centers. This includes countries in which carpets are uncommon and areas with a low prevalence of house dust mite sensitization. Perhaps the most important conclusion drawn from this study is that mold exposure and not carpet has an adverse effect on asthma symptoms and bronchial responsiveness.

The Swedish Institute for Fibre and Polymer Research reported a study on the association between allergens (an asthma trigger) and carpets.^{Ref. 29} The Swedish Institute presented factual evidence showing that there was no direct correlation between the frequency of allergic diseases and the use of carpets. The use of carpet in Sweden has steadily decreased between the mid-1970s and 1992. The market share of carpet in the 1975 was 40%. This has since fallen to about 2% in 1992. During this same time period, the incidence of allergies among Swedes has increased approximately four-fold. The study authors believe that allergic reactions in sensitive individuals are not directly associated with carpet, but rather indoor air quality.

Symptoms of asthma and the home environment were evaluated in Germany.^{Ref. 30} This study was based on two cross-sectional surveys (1995-2000). The survey data was analyzed for the prevalence ratio of several indoor exposures and asthma-related outcomes in 6- to 7-year-old children adjusting for confounders. Positive associations were observed regarding exposure to molds, environmental tobacco smoke, cooking with gas, and space heaters with fossil fuels. Most associations, however, were not statistically significant. The presence of carpet in the home was negatively associated with most respiratory conditions.

A Norwegian study examined the relationship between indoor exposures and respiratory symptoms.^{Ref. 31} In 1996-7, a community-based sample was collected from over 2400 adult subjects. Logistic regression was used to examine the relationship between eight markers of indoor exposure and physician-diagnosed asthma. Mold exposure was associated with all respiratory symptoms surveyed. Keeping a dog or cat in childhood was associated with dyspnea. Having a fitted carpet in the bedroom was negatively associated with respiratory symptoms.

Another German study investigated the relationship between indoor environmental risk factors and respiratory symptoms in 7-8 year old children.^{Ref. 32} Parents of 781 children with respiratory complaints and an equal number of randomly selected controls were asked to complete a questionnaire, including questions on indoor environmental conditions. Environmental tobacco smoke and pets increased the risk of asthmatic symptoms. An inverse association with asthmatic symptoms was seen for wall-to-wall carpet.

Australian researchers investigated the role of infant bedding items, as part of a composite bedding environment in the development of childhood wheezing.^{Ref. 33} Composite bedding categories were developed that corresponded to increasing numbers of house dust mite-rich bedding items used. Survey outcomes measured included recent and frequent wheezing. Composite infant bedding was associated with recent wheezing. Wheezing was further enhanced by home environmental factors of bedroom heating, recent painting and the absence of carpet. When any 2 or more of these environmental factors was present, a strong dose-response relationship was evident.

Allen Hedge, Ph.D., an indoor environmental expert, presented a paper at the 2001 annual meeting of the Council of Education Facility Planners.^{Ref. 34} Dr. Hedge states that “concerns that carpeting in schools is contributing to an increase in respiratory problems, allergies and asthma in schools are unfounded. As long as schools keep floors clean and use high-efficiency microfiltration vacuum bags, carpets can be a healthy, safe and economical floor covering in schools and day care centers. Microfiltration bags will trap very small particles, such as dust mites and feces, so that these will not become airborne.” Dr. Hedge reported that carpet can improve indoor air quality because carpet captures and holds dirt, contaminants and allergens that would otherwise become airborne.

In a paper presented at the 1996 International Indoor Air Quality Conference, the relationship between reported allergy symptoms, relative humidity, and airborne biologicals in thirteen Florida classrooms encompassing six schools was reported.^{Ref. 35} This study measured levels of airborne and surface fungi, bacteria, and dust mite allergens. Indoor and outdoor temperature and relative humidity were also measured. No airborne dust mite allergen could be detected in air even though it was found in some carpet. Health complaints, musty odors and visible mold growth were found to be associated with high indoor relative humidity. The study authors conclude that “there is no indication from this study that carpet contributes to the air quality problem. Carpet can serve as a reservoir for non-viable spores that enter from the outside, yet there is no

evidence to indicate mold spores or mite allergen leave the carpet. This study and others show that biologicals can be significantly removed from carpet by cleaning.”

The hypothesis that school classrooms with wall-to-wall carpet has a negative effect on children was tested in a Dutch study.^{Ref. 36} A group of asthmatic patients were selected from a Children’s Hospital. All children had peak-flow measurements three times a day for a 1-month period. Parents of the children completed a diary in which respiratory symptoms and medication use were recorded daily for the same period. Dust samples were collected from the classroom floors, living room and bedroom floors and mattresses of the children. Samples were analyzed for the major allergen of the house dust mite. There results of the study show that there was no significant difference in peak-flow measurements, acute respiratory symptoms or medication use between children in schools with or without carpet. The dust mite content of classroom floors was much lower than that of dust collected from homes. There was a significant correlation between peak-flow variability and mattress dust mite content. Thus carpeted classroom floors do not contribute to asthma symptoms or severity.

In an American study, 4634 elementary school students were examined with regard to asthma symptoms and parents completed household questionnaires.^{Ref. 37} Criteria for asthma included spirometry testing. Exposures in the home consistently associated with asthma diagnosis included environmental tobacco smoke, presence of dampness/mold, roaches, and furry pets in the home. The study authors reported that carpet in the child’s room was associated with lower rates of asthma medication use and school absenteeism.

A very recent review paper surveys the medical literature with respect epidemiological studies on associations between indoor residential chemical emissions and respiratory health or allergy in infants or children.^{Ref. 38} Twenty one studies are referenced in this publication. The study authors notes that available studies are limited in number and quality and that causal relationships have not been demonstrated. However, the authors claim that some common indoor materials in residences, including formaldehyde-emitting materials, flexible plastics, and recently painted surfaces are associated with adverse respiratory and allergic effects. Formaldehyde is the most consistently identified risk factor. The body of evidence cited by the authors suggests a need to better evaluate the risks of respiratory and allergic health effects from many common residential materials. While carpet is given mention in the article, it is not identified as a common risk factor. Overall, this paper may be useful to assess research strategies for further investigations. However, in the absence of causal relationships, inferences related to children’s respiratory health and carpet based on this survey paper cannot be established.

In 1993, the U.S. National Heart, Lung, and Blood Institute collaborated with the World Health Organization to convene a workshop that led to a report entitled Global Strategy for Asthma Management and Prevention. An annual report of this group captures important updates to the initial 1993 meeting.^{Ref. 6} The 2007 Annual Report includes a chapter on Prevention of Asthma Symptoms and Exacerbations. Table 4.2-1 of the Annual Report shows the effectiveness of avoidance measures for some indoor allergens.^{Ref. 39} Replacing carpet with hard flooring is listed as one possible avoidance

measure for both house dust mites and pets. In so far as a clinical benefit is concerned, replacing carpet to impact house dust mites or pets has no health impact. Thus, one of the most important reports in 2007 regarding asthma and prevention measures makes passing reference to carpet and states there is no evidence that replacing carpet has a clinical benefit. This is a very important statement and perhaps summarizes what is stated in the overwhelming view of clinicians and others that have studied this topic.

In conclusion, a weight of evidence approach to evaluating existing medical and scientific studies is quite clear. **Carpet does not cause asthma. VOC emissions from new carpet do not act as triggers for asthma or allergies. Carpet does not increase the incidence or severity of asthma or allergies in children and adults. From the standpoint of asthma and allergies, well maintained carpet is safe.**

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