Wool Carpet and Indoor Air Quality

Because we spend as much as 90% of our time indoors, it is important that we keep these environments as comfortable and healthy as possible – hence the modern day emphasis on indoor environmental quality, to which indoor air quality makes a significant contribution.

Polluted indoor air can result in discomfort, reduced efficiency and even ill health amongst building occupants. Gases produced by cooking and heating, as well as emissions from building materials and many commonly used household products, all contribute to poor indoor air quality. Wool has been shown to chemically react with some of the more common pollutant gases, neutralising and, in some cases, binding them irreversibly in its structure. Similarly, there is now considerable evidence that chemicals emitted from wool carpets do not pose any threat to the quality and safety of the indoor environment.

These attributes were recognised in the LEED (Leadership in Energy and Environmental Design) environmental building programme which accepted wool carpets as the only soft floorcovering in the initial testing of floorcovering products.

Wool carpet improves indoor air quality

Increasingly, we are living and working in energy-efficient buildings that often lack sufficient fresh air ventilation, resulting in pollutants becoming trapped inside. The most common indoor pollutants include combustion products, such as sulphur dioxide and nitrogen oxides, and formaldehyde, which is commonly used in resin-based wood products and other building materials. Emissions from cooking and heating with gas or solid fuels have been found to affect the respiratory health of children [1] who, because of their lower body mass, are more susceptible. In addition, the build-up of indoor pollutants has been widely linked with sick building syndrome, the effects of which can be costly in terms of reduced efficiency and productivity, and increased absenteeism.

New Zealand researchers [2], using a purpose-built controlled environmental chamber, have demonstrated that wool carpet can reduce high levels of introduced formaldehyde to virtually zero in 4 hours (Fig). Earlier experiments with nitrogen dioxide produced similar results, although the absorption rate was slower [3]. In contrast, nylon carpet was shown to have a much more limited ability to absorb these gases, a much slower rate of absorption and was less able to reduce the final concentrations to the very low levels achieved by wool. Furthermore, wool carpet was shown to retain the gases when heated, as would occur with underfloor central heating, while nylon carpet, which absorbed nitrogen dioxide to a considerably lesser extent, also re-emitted it more readily.

Studies by the US Gas Research Institute [4], which compared 35 building and furnishing materials, also showed that wool carpets have one of the highest removal rates of nitrogen dioxide (Fig). In contrast, the removal rate of synthetic fibre carpets was less than half that of wool. Although wallboard and cement blocks have higher removal rates, they become saturated more quickly. Wool carpets, on the other hand, because of their three-dimensional nature, present a considerable fibre area for the absorption of gases. For example, 1 m^2 of carpet containing 1 kg of wool in the pile actually represents a fibre surface of at least 100 m^2, whereas the same area of painted wall surface will still only provide 1 m^2 for absorption [5].

Research by the Environmental and Medical Sciences Division of the UK Atomic Energy Research Establishment [6] has shown that large amounts of sulphur dioxide are also irreversibly absorbed by wool pile carpets.

Volatile organic chemicals (VOCs) in indoor air have received considerable public health attention in recent years, as, at high enough concentrations, they can cause eye, nose and throat irritation, as well as aggravate allergy and asthma symptoms. In the worst case scenario, some VOCs can cause neurological disorders, organ failure and even cancer. In laboratory experiments, out of a range of building materials, which included carpet, gypsum board, upholstery, vinyl and wood flooring, and acoustic tiles, carpet was shown to be the most significant sorptive sink for non-polar VOCs [7]. A

survey carried out by Health Canada [8] of 96 homes in Quebec during winter and early spring, when windows would usually be closed, found that the presence of carpet was associated with lower concentrations of the VOCs benzene, styrene, 1,2,4-trimethylbenzene and ethylbenzene, which also suggests that the carpets were acting as a sink for these VOCs.

Carpet emissions shown to pose no threat to health

Depending on its composition and construction, carpet will emit different VOCs, generally between 3 and 40, with most emitting fewer than 10, the majority of which only being detectable at trace levels [9]. From an extensive toxicity analysis of over 300 chemicals likely to be related to carpets, Environ Corporation concluded that there is no reason to believe that chemicals in or emitted from carpet present any public health risk [10]. The use of two potentially problematic chemicals, formaldehyde and pentachlorophenol, has been banned in textile floorcoverings for around two decades.

The VOC emissions from carpets are only a fraction of those emitted by other materials used in buildings, for example, as illustrated in Fig (Venture Pamphlet-AQS), paint produces 200 times and wallcoverings nearly 17 times more VOC emissions than carpet. Every day, we emit VOCs into our environments as bioeffluents, and through activities such as smoking and using adhesives, polishes, fragrances, deodorants, air fresheners and computers. However, most are harmless in the concentrations normally found in everyday living.

While carpet has been singled out as a major source of VOC emissions, the rest of the carpet system, particularly adhesives and seam sealants, which also emit considerable quantities of VOCs, has been overlooked. To this end, it is worth noting that after laboratory testing of carpet samples collected directly from the production line of several manufacturers, together with underlay, the US Consumer Product Safety Commission concluded: “The Commission does not currently have evidence that specific chemical emissions coming from carpet are responsible for the health complaints associated with carpet installation.” [11]

In addition, carpet is often installed as part of other renovation work, such as painting and new joinery and cabinetry which, as noted above, can emit total VOCs orders of magnitude higher than carpet. The Health Canada survey, mentioned above, concluded that building occupants were exposed to VOCs from multiple sources, with combustion and recent renovation activities being the most predominant [8].

An extensive review of the evidence regarding the toxicological impact of new carpet emissions on indoor air quality and human health, which encompassed over 400 references, has been carried out by researchers from Cornell University [9]. They concluded that: “All of the analyses reviewed suggest that emissions from new carpets are insufficient by up to three orders of magnitude to pose any significant health risk.” They also considered that, from the available evidence, VOC emissions from carpets should not adversely affect indoor air quality.

In another review paper [12], Dr Mitchell W Saueroff, University of Connecticut Medical School, cites a 1992 study undertaken for the US Environmental Protection Agency (EPA), which conducted emission tests on 19 different carpet samples. Of the 69 chemicals identified, more than half came from just one carpet sample and only six of the compounds were emitted from more than 50% of the samples tested. He also points out that while carpet is discussed in a number of reports by organisations such as the EPA and the American College of Medical Toxicology, none of them lists carpet as a major heading or class of indoor pollutant. Furthermore, he notes that there is little opportunity for the emission chemicals to enter the body under conditions of normal use of carpet, further limiting their potential for toxicity.

New homes and offices exhibit a distinctive odour which results from VOCs emitted by items such as paint, particle board, furniture and carpet. This "new house" odour diminishes rapidly because of ventilation and declining emissions, and so usually lasts only a few weeks, while for wool carpets, approximately 90% of the VOCs dissipate within 2 days of installation [13]. A US study of VOCs

released by samples of four new carpets collected directly from the manufacturers' mills and packaged to preserve their chemical integrity showed that the concentrations and emission rates of most compounds decreased rapidly over the first 12 hours. This initial period, in which the decay rates were exponential, was followed by a period of slower decay and at the end of the week-long experiments, the concentrations of all but one compound were 10 parts per billion or less [14].

For carpets, the “new odour” is largely due to 4-phenylcyclohexene (4-PC), which, because it has a very low odour threshold, even at trace levels it can still be detected by the human nose. 4-PC is a by-product formed during the polymerisation of styrene-butadiene rubber (SBR) latex used to hold the fibres to the backing, and most of it will have been evaporated away during manufacture. Toxicology studies have shown that 4-PC is not a health hazard at the levels experienced from carpet [15]. Nevertheless, keeping rooms well ventilated during installation and for a few days after, will ensure the 4-PC odour and other VOCs will dissipate rapidly. In addition, modern adhesives have significantly lower VOC emission levels. The Carpet and Rug Institute “Green Label” certification for environmentally friendly carpet in the US, has a testing and labelling programme to certify carpets, underlays and adhesives meeting stringent VOC emission standards.

Because of the plasticisers used in its manufacture and the fact that it often requires high solvent materials for maintenance, vinyl flooring has been identified as a contributor of VOCs to the indoor environment [15]. A 2-year study in Oslo found a positive correlation between vinyl flooring and respiratory problems in infants [16]. For wooden flooring, although new water-based polyurethane varnishes are available, many varnishes and other floor finishes also give off large quantities of VOCs into the air, while formaldehyde can also be present in laminated pressed wood floorings [15]. During their lifetime, vinyls and wooden floors are frequently polished, a process which leads to high VOC levels. In contrast, vacuuming and wet cleaning of carpets are low VOC processes.

A number of cleaning products contain volatile organic compounds (VOCs), which have the potential to cause eye, nose and throat problems, headaches and skin irritation; others simply produce unpleasant odours that can also be a problem to some people. Results from carpet cleaning studies have shown that VOC emissions are up to 5 times lower than those from the cleaning of hard floor surfaces, with the latter exceeding acceptable values by as much as 50 times [17].

Wool carpet is naturally healthier

The complex chemistry of the wool fibre enables it to bind pollutant gases chemically in its structure, and it has been estimated that wool carpets can continue purifying indoor air for up to 30 years [5]. Formaldehyde has a high reactivity to the amino acid side-chains of proteins and since the wool fibre is largely composed of keratin protein it is able to effectively and permanently remove formaldehyde from indoor air. German researchers installed wool in five buildings with formaldehyde concentrations above the World Health Organisation (WHO) recommended level of 0.05 ppm, and within 24 hours, the levels in all five had dropped below that value [18]. Similarly, wool’s high acid-combining potential means that pollutants such as sulphur dioxide are chemically, and hence irreversibly, absorbed by the carpet pile.

Wool carpets have been shown to soil less rapidly than many of those made from synthetic fibres and consequently the reduced use of cleaning chemicals makes a positive contribution to the indoor environment. Wool is also naturally stain resistant and does not require treatments that may contain solvents such as fluorocarbons, formaldehyde and acetone or stain repellents such as silicones, acrylic co-polymers and fluorochemicals. Likewise, because wool is naturally flame resistant, wool carpets are not routinely treated with brominated hydrocarbons or organo-phosphorus flame-retardants, which have also raised indoor air quality and health concerns [19].

In the past, concerns have been raised about the health aspects of permethrin used to impart insect resistance to wool carpets. However, insect-resist agents used on wool carpets are increasingly being applied using low (or zero) effluent techniques and, once applied, are durable and totally safe to humans and pets. A study carried out in 80 private homes with wool carpets in the German city

of Hanover showed that permethrin concentrations in the air were very low, with likely inhaled levels well below the allowable Acceptable Daily Intake in food. The 145 occupants tested had similar concentrations of permethrin metabolites in their urine to those of the general population in Germany [20]. This led the researchers to conclude that there were no indications from their results of an adverse health effect due to carpet treatment by permethrin. As a result of comprehensive testing, the German Federal Health Office concluded that permethrin treatment of carpets "cannot be assumed to cause a significant health risk", while similar views are shared by the WHO and US EPA [21].

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