



THE SAFETY OF WOOD FLOOR COATINGS: A UL REPORT





EXECUTIVE SUMMARY



Coatings and other chemical treatments used in conjunction with wood flooring products are essential in providing resistance to scratches and other damage while helping to preserve a floor's surface appearance through years of use. However, organic solvents used in some floor coating products can be harmful to human health and can have a significant environmental impact.

Although efforts to regulate the use of these solvents has increased in recent years, especially in paint and paint products, a number of solvent-based floor coatings are still on the market in the U.S. In addition, many so-called Volatile Organic Compounds (VOCs) free floor coating products still contain chemicals of potential concern, placing consumers at risk.

As part of our ongoing research into the safety of chemicals used in industrial, commercial and consumer applications, UL has recently completed a study in which a variety of solvent-based and water-based floor coating products were tested for airborne emissions in simulated indoor environments. This white paper reviews the results of that testing, discusses the implications of the testing results, and provides recommendations for manufacturers and retailers on how they can assist contractors and consumers in making appropriate decisions regarding floor coating products.

SOLVENTS AND OTHER CHEMICALS USED IN COATINGS FOR WOOD FLOORING PRODUCTS

At their most basic level, coatings used in wood flooring products consist of natural or synthetic resins that have been dissolved into some form of chemical solvent, often along with other chemicals such as driers, fillers, and sometimes pigments or other coloring agents. In practice, floor coating products are often comprised of dozens of different chemicals and chemical combinations, each of which contribute to a product's unique properties and its usefulness in specific flooring applications.

In recent years, the coatings industry has introduced new chemical formulations and other innovations to reduce or eliminate the reliance on solvents. As a result, floor coating products available on the market today generally fall into one of three categories, as follows:

- **Solvent-based coatings**—Legacy solvent-based coatings typically include complex mixtures of organic solvents, including turpentine, white spirits (also known as mineral spirits), solvent naphtha and Stoddard solvent.
- **Clean water-based coatings**—So-called clean water-based coatings incorporate reactive diluents that are integral to the resin and can't be emitted from the coating system during application. Alternatively, some clean water coatings use temporary solvents that are stripped off in the manufacturing process.
- **Traditional water-based coatings**—Instead of organic solvents, water-based coating products use water as the primary solvent, along with water-compatible solvents, primarily n-methylpyrrolidone (NMP).

Innovations in floor coating products can be expected to continue as coating manufacturers evaluate new and alternative chemicals and chemical formulations that can provide safer and cost-effective coating solutions.

HEALTH RISKS ASSOCIATED WITH EXPOSURE TO CHEMICAL COATINGS

The continued availability of solvent-based wood floor coatings, and even some traditional water-based coatings, presents a number of health risks to both contractors who install wood flooring products and consumers who live with them. In both cases, the primary health concerns stem from exposure to volatile organic compounds (VOCs) generated by coating products.

VOCs are gases that are emitted from a variety of solids or liquids, including organic solvents. It is estimated that more than 11,000 different compounds are emitted from various types of

products, including paints, varnishes and coating products, household cleaning supplies, and even personal care products. According to the U.S. Environmental Protection Agency (EPA), concentrations of many VOCs can be as much as 10 times greater indoors than levels found outdoors, and can be as much as 1000 times greater than outdoor levels following the completion of certain activities, such as painting or paint stripping.¹

While some VOCs are known to be more toxic than others, only a small fraction of VOCs have been evaluated for health effects. Several VOCs detected in this research on coating product emissions have been linked with health concerns, including cancer and reproductive toxicity.

THESE INCLUDE:

- **ETHYLBENZENE**—Used primarily in the production of styrene, ethylbenzene is also used as a solvent. The EPA has determined that short-term human exposure to ethylbenzene is associated with respiratory effects, including throat irritation, irritation of the eyes, and neurological effects such as dizziness. In animal studies, long-term exposure has resulted in an increased incidence of kidney and testicular tumors in rats, and lung and liver tumors in mice, as well as reports of developmental effects.²
- **STYRENE**—Styrene is used in the manufacture of plastics, rubber, and resins. Indoor air is the principal route of styrene exposure for the general population. According to the EPA, acute exposure to styrene results in respiratory effects and chronic exposure results in effects of headache,

- fatigue, and central nervous system dysfunction. The International Agency for Research on Cancer has classified styrene as Group 2B, possibly carcinogenic to humans.³
- **2-ETHYLHEXANOIC ACID**—According to the National Institute for Occupational Safety and Health (NIOSH), short term exposure to 2-ethylhexanoic acid can be irritating to the eyes, the skin and the respiratory tract. In animal testing, long-term or repeated exposure has been shown as a possible cause of toxicity to human reproduction or development.⁴
- **N-METHYLPYRROLIDONE**—N-methylpyrrolidone (NMP) is found in many traditional water-based coating products. The U.S. EPA has determined that NMP is a reproductive toxin, and that high exposure to NMP poses a potential safety risk to pregnant women and women of childbearing age.⁵ Short-term effects also include respiratory problems.
- **FORMALDEHYDE**—Formaldehyde is a type of aldehyde used in solvent-based coating products. It is classified as a Group 1 known human carcinogen by the International Agency for Research on Cancer.⁶ The U.S. EPA's Integrated Risk Information System estimates a cancer risk in humans of one in 10,000 at relatively low concentration levels.⁷ Exposure to formaldehyde is also associated with decreased lung function and respiratory, eye, nose and throat irritation.
- **ACETALDEHYDE**—Acetaldehyde is another type of aldehyde found in solvent-based coatings. The U.S. EPA considers acetaldehyde to be a probable human carcinogen (Group B2), based primarily on animal studies. Other potential long-term effects include symptoms of chronic intoxication, similar to that experienced with alcoholism, and changes to the nasal mucosa and trachea. Short-term exposure to acetaldehyde can result in irritation of the eyes, skin and respiratory tract.⁸



It is important to note that the potential health and safety risks associated with these and other coating chemicals can vary significantly, depending on the nature and the extent of the exposure. For example, professional contractors may be subject to high exposure levels during the application of coating products, but can also reduce the risk through the use of masks, respirators and gloves. On the other hand, consumers may be exposed to considerably lower levels of VOCs emitted from coated wood products, but health and safety risks may be elevated due to prolonged and unprotected exposure. Furthermore, vulnerable populations such as children and pregnant and nursing mothers may be at increased risk from low-level exposures.

UL'S TESTING OF COATINGS FOR WOOD FLOORING PRODUCTS

To better understand the potential health and safety risks associated with wood floor coating products currently on the market in the U.S., researchers at UL's indoor air quality laboratory in Atlanta, GA recently tested 12 different, commercially-available wood floor coatings, representative of each of the three major coating chemistries used (i.e., solvent-based, traditional water-based and clean water-based). Samples of coating products selected for this evaluation were purchased through consumer retail channels and then sent to the Atlanta laboratory for use in the testing process.

TESTING PROCEDURES AND PROTOCOLS

To begin, initial screening tests were conducted to determine the type and amount of VOCs emitted from each floor coating sample. A single coat of each coating was applied to a solid wood substrate in accordance with the manufacturer's recommended instructions. Then, the coated substrates were placed in a test chamber supplied with purified air at standard conditions (23°C and 50 percent relative humidity) and with routine outdoor air ventilation rates (one air change per hour). After 24 hours, air samples were collected to determine emission rates for a range of VOCs. A summary of the screening test results is included in Table 1.

TABLE 1. VOC EMISSIONS SCREENING TEST RESULTS

UL SAMPLE ID (g/L)	VOC CONTENT (G/L)	TVOC EMISSION FACTOR AT 24-HRS (µG/M ² *HR)	PREDICTED TO MEET GREENGUARD OR GREENGUARD GOLD?	ETHYL BENZENE	STYRENE**	2-ETHYLHEXANOIC ACID	ACETALDEHYDE***	FORMALDEHYDE***	N-METHYLPYRROLIDONE	UNRESOLVED HYDROCARBONS
SOLVENT BASED 1	<450	20,600	NO	X		X	X	X		X
SOLVENT BASED 2*	<450	20,100	NO	X	X	X	X	X		
SOLVENT BASED 3	<275	17,900	NO	X		X	X	X		X
SOLVENT BASED 4	<450	12,200	NO				X			X
WATER BASED 1	<275	10,100	NO						X	
WATER BASED 2	<275	7,440	NO			X			X	
WATER BASED 3*	<275	6,350	NO						X	
SOLVENT BASED 5	<350	6,120	NO				X	X		X
WATER BASED 4	<275	6,080	NO						X	
WATER BASED 5	<95	3,330	YES							
WATER BASED 6	<275	2,620	YES			X			X	
WATER BASED 7*	<275	1,810	YES							

*COATINGS SELECTED FOR MORE COMPREHENSIVE LARGE CHAMBER TESTING.

** STYRENE WAS MEASURED DURING LARGE CHAMBER STUDY ONLY.

*** TRACE LEVELS OF FORMALDEHYDE AND ACETALDEHYDE WERE ALSO DETECTED FROM WOOD AND SUBTRACTED FROM THE COATING EMISSION LEVELS.

Based on the results of the screening testing, three formulations (a solvent-based coating, a traditional water-based coating and a clean water-based coating) were selected for a more comprehensive round of testing. Testing in this round was conducted in a room-sized environmental chamber, which was once again supplied with purified air and standard conditions and with routine outdoor air ventilation rates. The chamber was also equipped with a wooden floor to serve as a finish substrate for the coating products being tested and applied according to manufacturer's recommended instructions.

Testing during this round included both an application phase, corresponding with the period of time when a contractor applied the coating, and an "early occupancy" phase during which air samples were collected over a seven-day period following the final application of the coating. Background samples were collected prior to any testing to identify potential contaminants from the wood floor substrate.

During the application phase of testing for each formulation, a contractor poured a coating on the wood floor and spread it evenly over the entire surface using a standard synthetic wool applicator. Depending on the coating manufacturer's recommendations, one or two additional coats were applied at prescribed intervals with drying times ranging from two to 24 hours. Air samples were collected during each application of a coating to capture maximum breathing concentrations during the application, as well as over the total coating and drying period to determine an average breathing concentration during application.

The early occupancy testing phase started immediately after the final application of a coating. During this phase, air samples were collected six hours after the final coating was applied, then at daily intervals for four days, and with a final set of samples collected at seven days. Data taken at each of these sample points was then used to calculate emission rates over time for the coating under test, and to model predicted exposure concentrations in a typical office and residential environment.



TESTING RESULTS

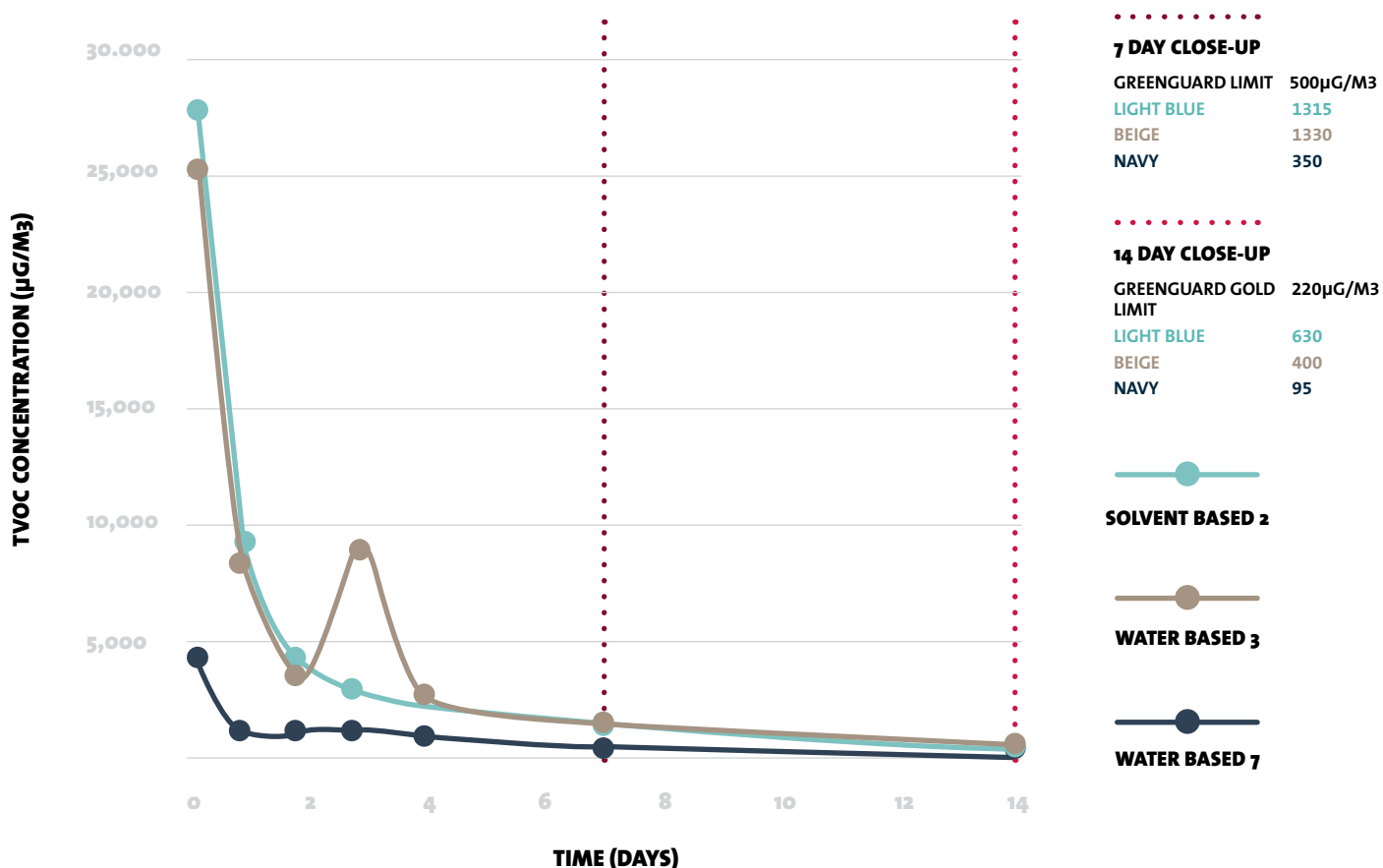
In analyzing the results of the testing, UL researchers compared the predicted exposure levels from the tested coating samples with recommended VOC exposure limits from various workplace health and safety agencies, as well as current industry occupational safety standards. The results were also compared with voluntary chemical emissions standards, for example, UL's GREENGUARD and GREENGUARD Gold limits.

Regarding VOC levels measured during the application phase of testing, some of the formulation samples generated significant airborne VOC concentrations as high as 15,000 $\mu\text{g}/\text{m}^3$. No individual VOC exceeded the maximum levels permitted under U.S. Occupational Safety and Health Administration (OSHA) limits, or the more current guidance levels set by the American Conference of Governmental Industrial Hygienists (ACGIH). Nonetheless, the potential,

long-term consequences of occupational exposure to these VOC emission levels from coating products may still pose a health risk to contractors. It should also be noted that these limits are developed to avoid harming industrial workers and are not considered protective for the general public.

However, the greater safety concern for consumers arises from the VOC levels observed during the second phase of testing, the early occupancy phase, which was designed to simulate emissions levels during the period of up to two weeks following the application of a wood coating product, when consumers might be reasonably expected to occupy that living space. In that phase of testing, both the solvent-based coating product and the traditional water-based coating exceeded permissible total VOCs (TVOCs) as prescribed under UL's GREENGUARD and GREENGUARD Gold standards. The TVOC exposure concentrations throughout application and early occupancy for each of the three coating systems are summarized in Figure 1.

FIGURE 1. PREDICTED TOTAL VOC EXPOSURE LEVELS DURING EARLY OCCUPANCY





Further, the solvent-based coating exceeded GREENGUARD Gold limits for 2-ethylhexanoic acid, a chemical which poses a significant safety risk to pregnant women and women of child-bearing age, while the traditional water-based coating exceeded GREENGUARD Gold limits for NMP, another potential reproductive toxin.

More in-depth results from UL's testing of VOC emissions from wood floor coating products are available at http://connect.ul.com/171013-ENV-WP-Safety-of-Wood-Floor-Coatings_download.html. UL's testing supports the continued concern about the safety of solvent-based and traditional water-based coating products used with wood floors, especially for consumers during early occupancy periods following the application of coatings.

FURTHER IMPLICATIONS FROM UL'S TESTING

In addition to the above findings, UL's evaluation and testing of wood floor coating products has several implications for retailers and consumers. These include:

- **COATING PRODUCT TERMINOLOGY IS OFTEN MISLEADING**—During the preliminary phase of testing, UL researchers found significant differences in VOC emissions between products promoted as “low VOC.” This designation is often used to refer to compliance with regulations to limit outdoor air pollution and ozone formation, and does not correlate to VOC emissions during indoor use. Unfortunately, the use of such subjective terminology perpetuates confusion and misunderstanding among retailers and consumers alike.

- **COATING PRODUCT LABELS ARE OFTEN INCOMPLETE**—In the same vein, information appearing on product labels may be incomplete or meaningless without context. For example, indicating content chemical concentrations in grams per liter (g/l) is meaningless to most buyers without a benchmark for comparison, while other critical information such as measured VOC emissions may be altogether absent from the label.

- **NOT ALL “WATER-BASED” COATINGS ARE CREATED EQUAL**—As our testing demonstrates, many traditional water-based coating products on the market produce potentially dangerous NMP emissions. Only more advanced, “clean” water-based coatings that incorporate reactive diluents are likely to be free of NMP and other potentially harmful chemicals.

- **SATISFYING OCCUPATIONAL EXPOSURE LIMITS IS NOT SUFFICIENT**—UL researchers determined that the real VOC risk from wood floor coating products comes during the early occupancy phase, after the contractor has left the project, and can last for weeks (or perhaps even months) after installation. Coating products that fail to meet more than just occupational limits may put consumers at increased risk.

- **THE INCREASED EXPOSURE RISK FROM “DIY” PROJECTS**—Although UL testing showed exposure concentrations below occupational exposure limits during the application phase of our testing, it did not account for additional risks that could be encountered by inexperienced contractors or by consumers engaging in “do it yourself” projects who don't use even the simplest of protective equipment such as face masks or gloves.

IMPORTANT CONSIDERATIONS FOR RETAILERS AND BRAND OWNERS

At present, the availability of cleaner wood floor coating products sold in the U.S. relies primarily on compliance with voluntary standards and guidelines, as well as competitive pressure among coating producers and brand owners to meet contractor and consumer expectations for environmentally-preferable products. Although stricter regulations for certain types of VOCs associated with coating products may be in the offing, retailers can implement product procurement policies that will increase consumer access to safer coating products.

An effective procurement policy for wood flooring coating products could include some or all of the following provisions:

- Implement a specified limit on VOC emissions from any coating product to be offered for sale, consistent with strict regard to health and safety considerations;
- Require manufacturers and suppliers to provide independent, third-party verification of the VOC emissions profiles for their coating products as a condition of procurement;
- Consider a ban on the procurement of any coating products that include chemicals or substances that have been classified as carcinogenic, mutagenic or reprotoxic, or endocrine disrupting, or which contain specific, potentially-toxic chemicals like NMP, ethylhexanoic acid and ethylbenzene;
- Actively promote to contractors and consumers those coating products that meet stringent VOC emissions criteria; and
- Perform periodic testing of finished coating products to help ensure their safety and their consistency with product chemical specifications.



THE BENEFITS OF UL GREENGUARD CERTIFICATION

The UL GREENGUARD Certification Program was developed to provide a mechanism to scientifically assess the chemical emission characteristics of products designed for use in indoor spaces. Certification is based on conformity with product-specific, performance-based standards that detail product sample collection procedures, testing methods and frequency of testing, and allowable emission levels based on established toxicity limits.

UL GREENGUARD Certification emissions limits were first used as purchasing specifications for the U.S. EPA and the State of Washington for furniture and commercial building products. Since 2002, UL GREENGUARD Certification criteria have been the basis for the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) credit for low emitting furniture.

The UL GREENGUARD Gold standard includes health-based criteria for additional chemicals, and also requires lower total VOC emission levels to ensure that products are acceptable for use even in the most sensitive environments such as schools and healthcare facilities. In addition to limiting emissions of more than 360 VOCs and total chemical emissions, UL GREENGUARD Gold Certified products must also comply

with requirements of the State of California's Department of Public Health "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers, Version 1.2 (2017)" (also known as California Section 01350).

UL GREENGUARD and UL GREENGUARD Gold Certified products are also subject to rigorous manufacturing review and ongoing testing requirements. The product documentation review and routine verification and retesting can help to quickly identify changes in a product's emission profile due to component modifications or revised manufacturing processes. As such, buyers have increased confidence that UL GREENGUARD Certified products are being consistently produced in accordance with the specified emissions levels.

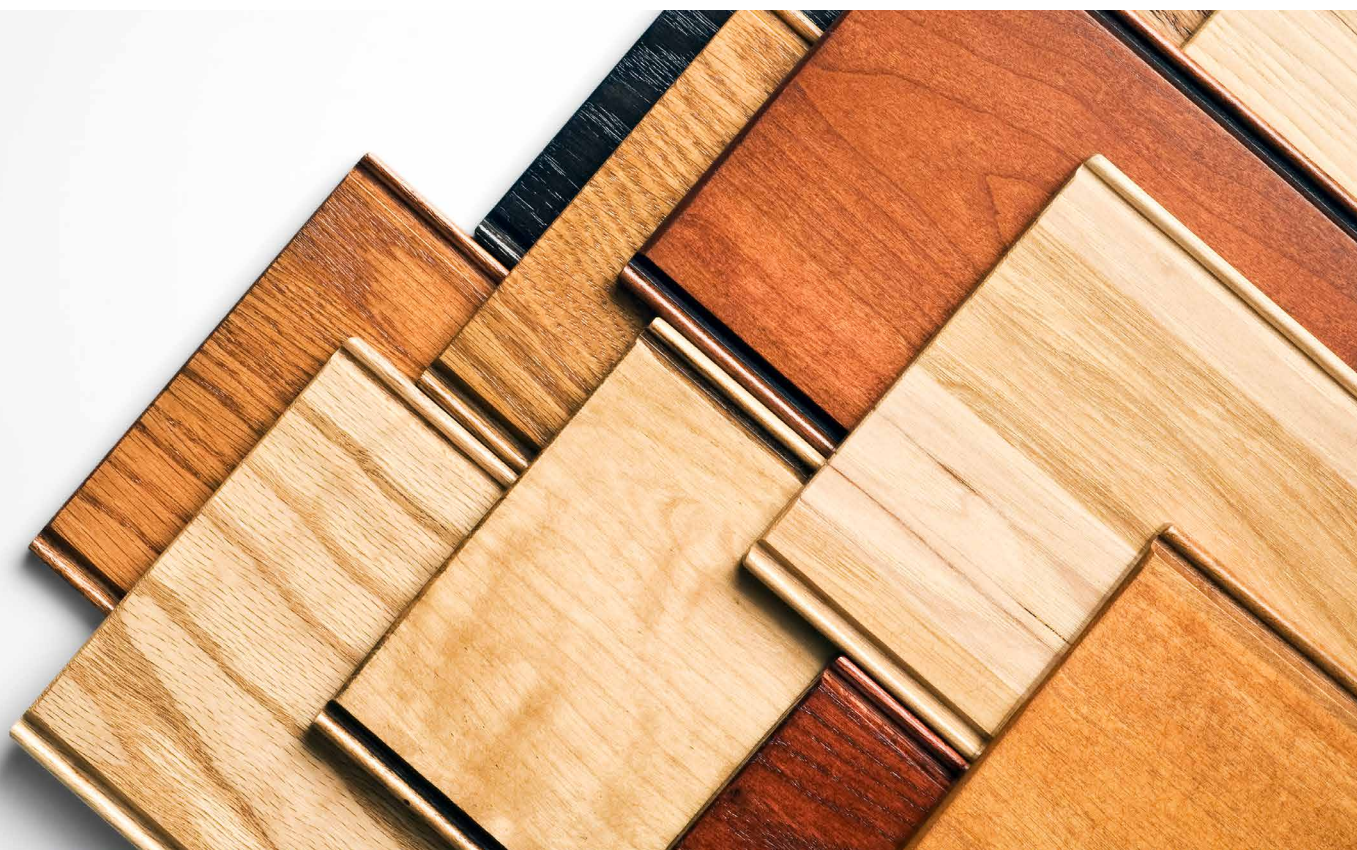
The UL GREENGUARD and GREENGUARD Gold Certification Marks are widely recognized and trusted by government purchasers, code officials, specifiers, and consumers. The broad acceptance of the UL GREENGUARD Marks provides greater market access for UL GREENGUARD Certified products, thereby providing manufacturers with important competitive advantages. UL GREENGUARD Certification serves as a testament to a manufacturer's commitment to the production of safer products.





SUMMARY + CONCLUSION

UL's recent assessment of VOCs from wood floor coating products supports ongoing concerns regarding their safety, especially among vulnerable populations including children and the elderly. It is clear, based on this research, that current labelling of VOC content in gram per liter does not accurately represent the potential consumer exposure. Clearly, continued research into chemical emissions from coatings and other building products, as well as ongoing innovation within the chemical industry, are warranted. In the meantime, retailers and brand owners alike can take important steps to bring safer coating products to the U.S. market, and to help educate contractors and consumers about the potential risks associated with legacy coating formulations.



For additional information on UL's testing of VOC emissions from wood flooring coating products, or on UL's GREENGUARD certification programs, contact us at ENVIRONMENT@UL.COM or visit UL.com/gg



END NOTES

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