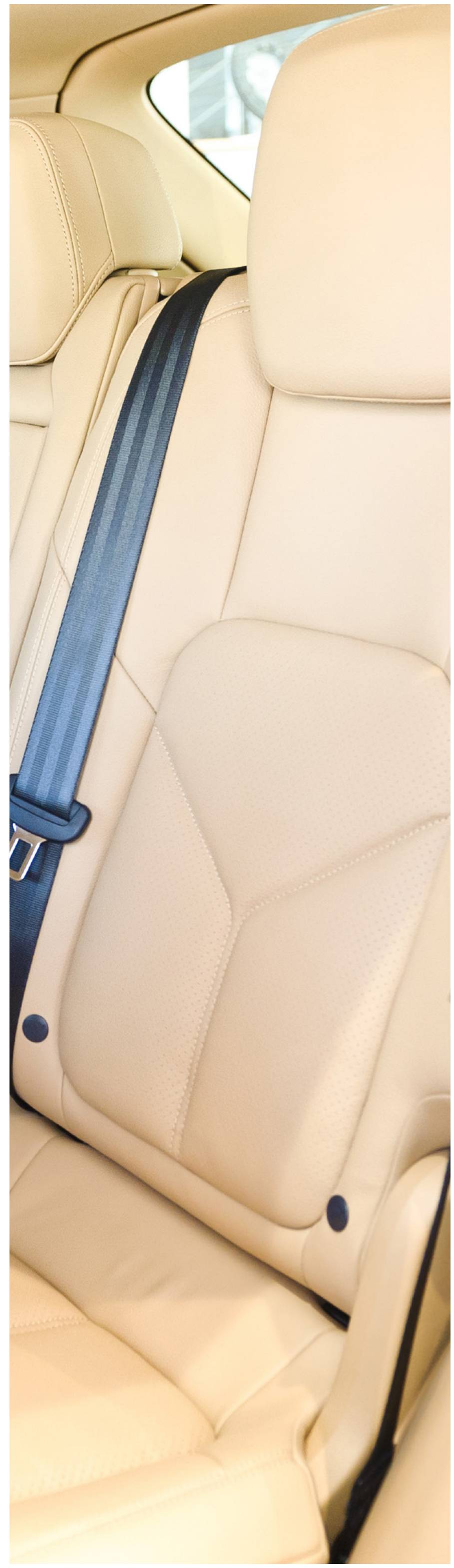
Vehicle Interior Air Quality: Addressing Chemical Exposure in Automobiles



The "new car" smell that used to be part of the appeal of buying or leasing a new automobile is now known to be the result of chemicals emitted from the myriad of parts and components that make up an automobile's interior space. From the dashboard to interior panels and seat coverings to flooring materials, the majority of automotive interior components are comprised of plastics and other materials that contain various amounts of volatile organic compounds (VOCs) and other chemicals. Unfortunately, within the confined space of an automobile's passenger compartment, concentrations of chemicals emitted from these components may reach levels that are potentially harmful to human occupants.

Although a number of countries have established regulations or guidelines regarding acceptable chemical concentrations in automobiles, it is the automotive industry itself that has been the principal force for implementing chemical emissions limits and testing requirements for automotive components. Chemical emissions testing and reporting is now an essential component procurement requirement for most major automobile manufacturers, even in cases where national regulations or standards do not apply. Therefore, component suppliers and original equipment manufacturers (OEMs) should be prepared to evaluate the chemical emissions profile of their products and submit to independent testing when required.

This UL white paper discusses the problem of vehicle interior air quality (VIAQ) and the methods for assessing chemical levels in automobile interiors. The paper begins with a summary of recent research on VIAQ, the types and levels of chemicals to which vehicle occupants are routinely exposed, and the potential health effects attributable to long-term chemical exposure. The white paper then provides an overview of global VIAQ regulations, requirements and standards and then presents information on various testing methods used to measure and assess VIAQ. The paper concludes with recommendations for automobile manufacturers and component suppliers for addressing VIAQ issues.

The Issue and Challenges of Vehicle Interior Air Quality

With people in modern societies spending as much as 90 percent of their time indoors, it is not surprising that factors contributing to poor indoor air quality are receiving significant attention from researchers, government officials and the general public. But, despite the fact that many people spend upwards of an hour each day in enclosed vehicles, comparably little attention has been given to vehicle interior air quality (VIAQ). Unfortunately, the relatively small interior space provided in most vehicles means that air concentrations of various chemicals and organic compounds may be as much as three times greater than in other indoor environments, depending on the age of the vehicle and other factors.

Chemicals affecting VIAQ can be attributed to a number of different sources within the vehicle passenger compartment. These sources typically include interior components and finishes used for structural or safety purposes or for aesthetic effect, which are made of a wide variety of materials such as hard plastics, elastomers, rubber, leather, fabrics, fibers and resins. Actual chemical concentrations in vehicle interiors may vary depending on a number of factors, including the age of the vehicle, exterior environmental factors such as heat, humidity and exhaust from other vehicles, and user habits (such as smoking in the vehicle).

Emissions of volatile organic compounds (VOCs) from interior parts are one of the principal contributors to VIAQ-related issues in both new and used vehicles. VOCs are composed of carbon-based chemicals that can vaporize into the air under the right conditions. VOCs are often part of the chemical composition of materials and components used in vehicle interiors, but can also be found in material adhesives as well as in cleaning materials and compounds used in preparing and maintaining vehicle interior surfaces.

Most research indicates that the highest chemical concentrations affecting VIAQ are typically found in new vehicles, when levels of off-gassing from newly installed interior components and fixtures are highest. Numerous studies have found the measurable presence of anywhere from 30 to more than 250 separate VOCs in a single vehicle, in total concentrations as high as 14,000 µg/m3. And, while concentrations of chemical emissions may decline as a vehicle ages, they can also quickly rebound when elevated vehicle temperatures stimulate vaporization of chemicals in interior finishes.

Chemical Compositions of VOCs in Vehicle Interiors and Their Effects

The Chemical Substance Inventory maintained by the U.S. Environmental Protection Agency (EPA) currently lists more than 84,000 individual chemicals and chemical compounds currently used in U.S. commerce. Although many of these chemicals are thought to be harmless, their full impact on human health is unknown, and the challenge of identifying potential human health effects further increases as new chemicals and compounds are introduced into use.

However, prolonged exposure to certain VOCs has been directly associated with an increase in the incidence of numerous health-related issues. The most common effects resulting from VOC exposure include, eye, nose and throat irritation, allergic skin reactions, headaches, dizziness, and fatigue. However, more serious impacts are also possible. For example, the incidence of asthma, which can often be triggered by VOCs, has reportedly doubled over the past 20 years and now affects one in every six Americans. The potential connection between VOC exposure and asthma is felt most acutely by children, since those exposed to high levels of VOCs are far more likely to develop asthma.

Further, some VOCs are either a known or suspected cause of some types of cancer found in humans. Indeed, a number of VOCs commonly found in vehicles have been classified as "carcinogenic," "probably carcinogenic" or "possibly carcinogenic" to humans by the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO). Other long-term health effects from prolonged VOC exposure can include anemia, leukemia and other chronic diseases, as well as reproductive disorders.

VOCs with the greatest potential toxicity to humans in vehicles include:

- Benzene—Classified as a Group 1 carcinogen by the IARC ("carcinogenic to humans"), benzene is produced as a by-product of combustion, such as that generated by vehicle engines. It is also used in the manufacture of other chemicals such as plastics and solvents. Exposure to benzene has been associated with increased rates of leukemia, lymph cancer and blood cancer. It is extremely dangerous when inhaled and exposure can also result in eye, nose and throat irritation.
- Formaldehyde—Formaldehyde is used in the production of adhesives used in fiberboard and particle board, and is also found in foam insulation and textile finishing treatments. Also classified by the IARC as a Group 1 carcinogen, formaldehyde has been associated with lung and nasopharyngeal cancers. It can also cause coughing, wheezing and chest pains, as well as eye, nose and throat irritation.
- Ethyl benzene—Classified as a Group 2B carcinogen by the IARC ("possibly carcinogenic to humans"), ethyl benzene is primarily used in the production of styrene. Exposure to ethyl benzene is associated with acute respiratory effects, such as throat

irritation, irritation of the eyes, and neurological effects such as dizziness.

- Styrene—Styrene is produced from a combination of benzene and ethylene and is used to manufacture plastics, resins and synthetic rubbers. Also considered to be a possible human carcinogen (IRAC Group 2B), styrene can produce central nervous system symptoms such as decrease coordination and concentration and impairment of short-term memory. Styrene exposure can also produce irritation of the eyes, skin, nose and the respiratory system, and can cause sleepiness or unconsciousness.
- Toluene—Toluene is used as an additive in vehicle fuels, in paints, varnishes and glues, and in the production of other chemicals. Toluene is classified in the European Union (EU) as a reproductive toxicant, and is also associated with a number of neurological effects, from muscle weakness, tremors and impairment of speech. Dermal exposure to toluene can cause skin irritation and blistering.
- Xylene—Xylene serves as a solvent in paints and inks, and is also used in the production of plastics, leather and rubber. Exposure to xylene may cause liver and kidney damage, and can also result in dizziness, headache or confusion. Skin contact with xylene can cause irritation and discoloration, as well as dryness, cracking and blistering.
- Acetaldehyde—Acetaldehyde is used in fuel compositions and as a solvent for rubber and leather tanning. It is also used in the production of polyester resins and basic dyes. Chronic exposure to acetaldehyde can result in symptoms similar to those of alcoholism in humans. Other potential effects include irritation of the eyes, skin and respiratory track.

Within the passenger compartment of a new vehicle, concentrations of each of these individual VOCs can often exceed levels deemed safe for extended human exposure. However, it is not possible to assess the potential additive effects of exposure to combinations of VOCs that characterize VIAQ under actual use conditions.

Global Regulations and Standards for Whole Vehicle VIAQ

Regulations or voluntary standards regarding permissible concentration levels of VOCs in new vehicles have been implemented or adopted in a handful of countries. However, these requirements and standards differ in important ways from each other in terms of which VOC concentrations are measured, the preparation of whole vehicle samples for testing, the duration of testing phases, and the analytic methods used to assess air samples.

Korea

Korea was one of the first countries to establish whole vehicle VIAQ requirements with the 2007 publication of its “Newly Manufactured Vehicle Indoor Air Quality Management Standard,” Notification No. 2007-539, issued by Korea’s Ministry of Land, Infrastructure and Transportation. The Notification prescribes emissions limits for seven specific VOCs, including formaldehyde, benzene, toluene, ethyl benzene, xylene, styrene and acrolein. In addition, the Notification details a specific test method for determining actual emissions levels, which include vehicle preparation, sampling duration and approved methods of VOC analysis.

China

China's voluntary national standard GB/T 27630-2011, "Guidelines for air quality assessment of passenger vehicles," was released in 2011 by China's Ministry of Environmental Protection and State Administration of Quality Supervision, Inspection and Quarantine. The standard, which came into effect in March 2012, prescribes different concentration limits for all but one of the seven VOCs accounted for in Korea's requirements (concentration limits for acrolein are the same), and adds limits for additional VOCs including acetaldehyde. GB/T 27630-2011 is currently being revised to become a mandatory national standard. The new version is expected to be released at the end of 2015.

The Chinese standard references the HJ/T 400 test method which also differs from those found in Korea's requirements, primarily an increase in sample preparation time and the duration period for sampling. However, the VOC analysis methods are similar to those found in Korea's requirements.

Japan

In Japan, the Japan Automobile Manufacturers Association (JAMA) published a voluntary set of "Guidelines for Reducing Vehicle Cabin VOC Concentration Levels" in 2005. The Guidelines include concentration limits for 13 separate VOCs consistent with indoor concentration levels previously established by Japan's Ministry of Health, Labor and Welfare. (Notably, concentration limits for benzene are absent from the Guidelines.)

Applicable measurement methods are described in a separate document, JASO Z 125, "Road vehicles—Interior—Measurement methods of diffused volatile organic compounds (VOC)," published by the Society of Automotive Engineers of Japan (JSAE) in 2009. JASO Z 125 provides extensive details on whole vehicle preconditioning (including air-conditioning settings), and includes testing in both unattended (closed) mode as well as driving mode. Methods of sample analysis are similar to those applicable in Korea and China. The biggest difference is that the Japanese standard involves heating the car with lights. Heating increases VOC emissions from interior parts and results in higher measured concentrations in the cabin interior.

Table 1: Comparison of guideline values in China, Korea and Japan

Compound	Guideline Value (mg/m3)		
	China (GB/T 27630)	Korea	Japan MHLW
Toluene	1.10	1.00	0.26
Xylene	1.50	0.87	0.87
Formaldehyde	0.10	0.25	0.10
Ethylbenzene	1.50	1.60	3.80
Styrene	0.26	0.30	0.22
Benzene	0.11	0.03	-
Acetaldehyde	0.05	-	0.05
Acrolein (2-propenal)	0.05	-	-
Paradichlorobenzene	-	-	0.24
Tetradecane	-	-	0.33
di-n-butyl phthalate	-	-	0.22
di-2-ethylhexyl phthalate	-	-	0.12

Russia

In Russia and other Eurasian Customs Union countries, test methods and regulations have focused not only on VOC emission from interior materials but also vehicle exhaust gases that can be found in vehicle interior air during driving. The national standard GOST R 51206, Pollutant Contents in the Air of Passenger Compartment and Driver's Cab, was developed in 2004 to set limits for combustion gases and certain VOCs. Cabin air levels are monitored in idling mode and while operating the vehicle at 50 km/hr. The maximum allowable concentrations defined for vehicles with different types of engines are summarized in Table 2.

Table 2. Maximum allowable concentrations from Russia's national standard

Pollutant	Maximum Allowable Concentration (mg/m3)	Engine Type
Formaldehyde	0.05	3,4,5
Nitrogen Dioxide	0.2	1,2,3,4,5
Nitrogen Oxide	0.4	1,2,3,4,5
Carbon Monoxide	5	1,2,3,4,5
Aliphatic Hyrdrocarbons (C2H6 - C7H16)	50	1,2,3
Methane	50	3,5

Engine Types

1 - Positive ignition engines

2 - Positive ignition engines - Liquified Petroleum Gas

3 - Positive ignition engines - Natural Gas

4 - Diesel engines

5 - Gas diesel engines

ISO 12219-1

The differences among the regulations and standards referenced above illustrate the significant testing challenges facing automobile manufacturers and OEMs seeking access to multiple national markets. As a result, there have been recent efforts to harmonize requirements for whole vehicle assessments of VOC concentrations in new automobiles. Most notable was the 2012 publication by the International Organization for Standardization of ISO 12219-1, Interior air of road vehicles – Part 1: Whole vehicle test chamber – Specification and method for the determination of volatile organic compounds in cabin interiors.

This test method was developed through a joint effort between ISO Technical Committee 146, Air Quality, and a working group of Technical Committee 22, Road Vehicles. ISO 12219-1 specifies VOC measurement sampling for passenger vehicles during three distinct modes of vehicle operation (ambient mode, parking mode and driving mode) in order to assess VIAQ under all anticipated operating conditions. VOCs and carbonyl compounds are measured during ambient and driving modes, while only formaldehyde is measured during parking mode. The standard also describes the sampling and analysis procedure to be used in assessing the collected samples.

Unlike the national regulations and standards previously mentioned, ISO 12219-1 does not prescribe concentration limits for individual VOCs. However, it is anticipated that the testing and assessment methods presented in the standard will help to minimize inconsistencies between individual national standards, thereby easing the process of whole vehicle testing.

Other Harmonization Efforts

Korea's Ministry of Land, Infrastructure and Transport has also been actively involved in promoting a harmonized set of requirements for VIAQ through its participation in the United Nations Economic Commission for Europe (UNECE) Working Party on Pollution and Energy (GRPE). In 2013, it submitted a proposal for a United Nations Global Technical Regulation (GTR) on VIAQ, GRPE-33-03, which calls on the UNECE to enact new regulations to minimize VOC emissions in new vehicles. An Informal Working Group (IWG) within the GRPE is currently working to create a draft GTR for review and comment. Meetings are expected to continue through at least 2017.

OEM Material and Component Testing

OEMs use material and component test data to manage VIAQ during the engineering and development process so that the final vehicles will meet all of the requirements in the various markets where they may be sold. At the automotive component and materials level, VOC emissions and testing requirements are addressed in a variety of ways, depending on the manufacturer. Automobile manufacturers headquartered in different regions typically adopt material and component testing requirements of that region. For example, Japan auto manufacturers adopt JAMA/JSAE standards, and European OEMs adopt standards developed by the Verband der Automobilindustrie (VDA, or German Automotive Industry Association).

Other major manufacturers may take a proprietary approach to test requirements for their supply chain by adopting some of the emissions and testing requirements of specific standards by reference, combining various elements of existing standards or developing entirely new requirements.

The various available material and test methods are being harmonized under the ISO 12219 set of standards. Table 3 includes a summary of material and component test methods being applied by automobile manufacturers in connection with efforts to address VIAQ.

Table 3: Material and component test methods for VOC emissions

Test Type	Reference standard	Test Apparatus Size	Temperature Profile
MATERIAL TESTS			
VOC Thermal desorption	VDA 278	4 mm Tube	90°C for 30 min, 120°C for 60 min
Formaldehyde Modified Flask Method	VDA 275	1 L Jar	60°C for 3 hours
Odor	ISO 12219-7 120°C for 60 min	1 L Jar	23, 40, or 80°C for 24 hours
VOC Headspace Method	VDA 277	20 mL	120°C for 5 hours
Micro-scale Chamber Method	ISO 12219-3	44 or 114 mL	65°C for 20 min
COMPONENT TESTS			
VOC Bag method	JASO M 902 ISO 12219-2	10 L – 2,000 L Bag	65°C for 2 hours with no air change
Static Chamber	ISO 12219-5	10 – 500 L Chamber	65°C for 4 hours with no air change
Dynamic Chamber	VDA 276 ISO 12219-4 ISO 12219-6	500 - 4000 L Chamber	65°C for 4 hours at 0.4 air changes per hour

Material tests allow OEMs and suppliers to detect problem materials early in the development cycle. There are wide variations in the methods used by global OEMs for materials screening testing to measure odor, VOCs and formaldehyde. The tests are typically conducted on a small coupon of a material such as a textile, foam or adhesive.

Material test data is used to identify which chemicals are emitted from specific materials. The various test methods use different equipment and different temperature profiles, which makes it difficult to compare data among methods. Data from samples tested by the same method can be compared to identify low emitting materials that can be used in interior components to reduce cabin VOC levels.

Component tests are generally conducted on finished interior parts such as a seat, headliner or carpet assembly. Testing is conducted in either large bags or in dynamic environmental chambers. Bag methods provide semi-quantitative emissions data that can be used to compare emissions among components or to qualify against an internal specification. Dynamic chamber methods have the added benefit of modeling the result to predict the cabin concentration in the final vehicle.

UL has developed a system for measuring all interior components in a vehicle using the chamber methodology. Chamber conditions can be controlled to match the vehicle environmental conditions of any of the national guidelines for VIAQ. Data from all of the interior components are used in a computer model to predict the airborne concentrations in the new vehicle. This technology helps OEMs detect potential issues prior to starting assembly.

Regardless of the path taken by an individual automobile manufacturer, supplier compliance with VIAQ requirements is typically managed though the manufacturer's purchasing process as a condition of procurement. Component and material suppliers are often expected to submit test reports and other evidence demonstrating compliance with applicable requirements as part of the bidding process or before a procurement contract is executed.

Recommendations for OEM Compliance

The breadth and diversity of requirements and standards intended to address VOC concentrations in new automobiles can present a daunting compliance landscape for suppliers of automotive components and materials. OEM suppliers should consider taking the following steps to best meet this challenge:

- *Assess your product*—Components can frequently be redesigned or reconfigured to reduce the presence of VOCs. Where possible, use materials with lower VOC profiles. Check paints, varnishes and finishes for chemical contents and seek reduced or VOC-free alternatives. Consider integrating components in the design stage to reduce the need for adhesives.
- *Identify your target markets*—VOC requirements and standards can vary widely based on geography and targeted manufacturers. Knowing the specific requirements and testing protocols for your target markets can better prepare you for whatever testing may be required, allow you to better coordinate testing efforts, and help minimize the need for duplicate testing.

- *Partner with your customers*—As concerns grow about the potential health risks associated with poor VIAQ, automobiles with superior VOC emissions profiles are likely to gain increased visibility with consumers. Creating an effective working partnership with automobile manufacturers to address VIAQ concerns can help both parties, and result in increased market share.
- *Seek expert guidance*—Automotive component and material suppliers who fail to adequately address VOC considerations for their products will be at a competitive disadvantage in the global marketplace. Working with an organization experienced in the full array of testing methods applicable to measuring VOCs can help streamline the product approval process and result in more rapid acceptance of your product by automobile manufacturers.

Summary and Conclusion

Concerns about potentially harmful concentrations of VOC in indoor environments now extend to the interiors of automobiles and other vehicles, where VOC concentrations can be as much as three times greater than in indoor spaces. As a result, regulations and standards are emerging to reduce VOC concentrations and improve the overall quality of air in vehicles. However, applicable VOC regulations, standards and testing protocols depend on the components or materials subject to testing, and can also vary considerably from automobile manufacturer to manufacturer. These complexities can quickly result in unnecessary duplicate testing, delays in product acceptance and lost market opportunities.

For both automobile manufacturers and suppliers of automotive components and materials, UL is a globally respected leader in the effort to improve VIAQ. For more than (25 years), we have conducted pioneering research in indoor air quality applicable to a broad range of products. Our testing facilities are fully equipped to support OEM suppliers with whole vehicle VIAQ testing, as well as component and material testing. Further, UL works with automobile manufacturers worldwide to develop VIAQ requirements and supply chain programs to meet both regulatory and proprietary VOC emissions requirements.

For further information about UL's indoor air quality and vehicle indoor air quality services, contact environment@ul.com or visit http://services.ul.com/service/vehicle-interior-air-quality-testing/.

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