INDOOR AIR QUALITY HAZARDS

OF NEW CARS

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Indoor Air Quality Hazards of New Cars

While the new car smell is a cultural icon and a source of pride when showing off a new car, results of recent studies indicate that levels of airborne chemicals in new car interiors are significantly higher than is recommended for today's indoor environments. The danger does not totally go away as the new car smell fades and levels of these chemicals drop over time, but can increase when excessive heat builds up in lock cars during the summer months, causing the levels to rise again.

The chemical mixture is comprised of volatile organic compounds (VOCs), including formaldehyde; polybrominated diphenyl ethers (PBDEs), used as flame retardants; and phthalic acid esters (phthalates), which are emitted from materials and finishes used to make car interiors, such as plastics, wood, leather, textiles, seat cushions, glues and sealants. Exposure to these substances can exacerbate allergy and asthma symptoms and cause eye, nose and throat irritation; cough; headache; general flu-like illnesses; and skin irritation. Some also are known to cause cancer and neurological effects.

This paper reviews the results of research that demonstrate that levels of VOCs, PBDEs and phthalates in new car interiors can be very high, the efforts by some automakers to lower levels in new cars and what consumers can do to protect themselves.

VOCs and Indoor Air: A Bad Blend

Volatile organic compounds are carbon-based chemicals, which under the right conditions can evaporate into the air – hence the term "volatile." As with other types of indoor environments, materials and products used in car interiors frequently have organic compounds as a part of their composition. Cleaning products and processes used in cars also contain compounds that can emit VOCs. In addition, some materials, even metals or glass, act as VOC "sinks", by absorbing VOCs emitted from other materials during periods of high concentrations or harboring VOCs on their surfaces. These materials later can be a significant source of VOC emissions that were not a part of their original composition.

Although there is not very much data on VOC levels in car interiors, the results from the few studies that have been done raise serious concerns, especially in light of what is known about how VOCs emissions can affect the health of people in other indoor environments, such as homes, schools and workplaces. Before considering the results of several of these studies, reviewing what investigators look for when evaluating indoor air quality (IAQ) in building interiors for VOCs will provide some perspective.

Typically, investigators measure the total amount of VOCs (TVOC) in the air and then compare those levels with the general guide in Table 1 to evaluate their potential effect on indoor occupants (Mølhave 1986). Investigators also look at levels of individual VOCs to ascertain which VOCs are present, which may have higher concentrations than others and which may present health risks to those exposed. This is helpful in determining which VOCs may be the cause of complaints as well as likely VOC sources.

Table 1. General guide to TVOC emissions and health effects

Less than 0.20 mg/m^3	No irritation or discomfort expected
0.20 mg/m^3-3.0 mg/m^3	Irritation and discomfort may be possible
3.0 mg/m^3-25.0 mg/m^3	Discomfort expected and headache possible
Greater than 25 mg/m^3	Toxic range where other neurotoxic effects may occur

As many as 100 to 1,000 different VOCs may be in the indoor environment where adults and children can easily inhale them. Long-term exposure even to small amounts of VOCs can adversely impact health. Children are at a greater risk for developing health problems as they breathe in more air with respect to their body size than adults and thus have greater exposure to VOCs and other indoor pollutants. Recent green / healthy building programs, such as the State of Washington and the US Green Building Council, have established 500 µg/m^3 of TVOC and 50 parts per billion (ppb) of formaldehyde as acceptable levels to clear a building for occupancy.

VOC, PBDE and Phthalate Levels in New Cars Extremely High

Researchers from Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) measured VOC concentrations in new cars from three manufacturers, beginning from when they were purchased on the Australian market to roughly two years later. Initially, TVOC levels were very high (up to 64,000 µg/m^3) in the two locally made cars, which reached the market one to two months after manufacture. These levels decreased approximately seven-fold in the first month, but still exceeded Australia's National Health and Medical Research Council (NHMRC) indoor air goal of TVOC not to exceed 500 µg/m^3 (one-hour average) and any VOC not to exceed 250 µg/m^3 (one-hour average). The third car was imported and reached the market four months after manufacture. The initial TVOC concentration was 2,000 µg/m^3 (Brown and Cheng 2000).

Overall, the most prevalent VOCs found in the new cars were benzene, a known human carcinogen; acetone, a mucosal irritant; ethylbenzene, a systemic toxic agent; and xylene isomers, fetal development toxic agents. The results also showed that decay of VOC concentrations occurred exponentially, with TVOC concentration decreasing by about 20 percent per week after manufacture. The NHMRC indoor air goal was reached after about six months (Brown and Cheng 2000).

Another study evaluated five different passenger sedan vehicles from three US automobile manufacturers both when parked, unventilated and under driving conditions, using air conditioning, vent mode or with the driver's window one-half open. The cars were three rental sedans less than six months old (two 1997 Ford Taurus and one 1997 Chevrolet Lumina) and two used sedans (1993 Toyota Camry and 1993 Ford Taurus) (Fedoruk and Kerger 2003).

When the cars were parked, total VOC levels were approximately 400 µg/m^3 to 800 µg/m^3 at warm interior temperatures (80 degrees F). Total VOC levels were at least five-fold higher under extreme heat conditions (up to 145 degrees F) than under the warm conditions. The profile of the most prevalent individual VOCs varied considerably depending on the vehicle brand, age and interior temperatures. Overall, the most predominant compounds found were styrene, toluene, and 8 to 12 carbon VOCs (Fedoruk and Kerger 2003).

The VOCs levels dropped dramatically during operation (50 μg/m^3 to 160 μg/m^3), with the lowest levels generally occurring when the driver's window was one-half open. The researchers noted that although the primary source of the VOCs was most likely the materials, sealants and adhesives used in the car interior, other sources may include outdoor air contaminants drawn in via the ventilation system or the open window, environmental tobacco smoke, chemical spills within the car, fuel exhaust or fumes leaking from the gas tank, deodorizers, and cleaning and conditioning products (Fedoruk and Kerger 2003).

The GREENGUARD Environmental Institute (GEI) recently completed a limited study of the passenger compartments of three automobiles (two of which were new and one was one-year old) and found more than 100 different VOCs, many of which were known irritants, odorants and carcinogens. Total VOC levels measured in Car 1, which had been on the lot for two weeks, were 2,137 μg/m^3 and for Car 2, which had been on the lot for two months were 767 μg/m^3. Interestingly, the third car, which was one-year old and the subject of a consumer complaint measured TVOC levels at 8,691 μg/m^3 – significantly higher than the newer cars. The primary compounds found included 2-ethyl 1-hexanol; trimethylpentanediol monoisobutyrate; phenol; naphthalene; benzenes; and many other alcohols, hydrocarbons, chlorinated chemicals, BHT and amines. Only Car 2 met the acceptable level of formaldehyde (50 ppb) used by US Green Building Council Leadership in Energy and Environmental Design (LEED) and GREENGUARD programs. Formaldehyde emissions were 60 ppb for Car 1 and 100 ppb for Car 3.

A fourth study measured VOC levels taken from a new 1995 Lincoln Continental during a typical summer day and again on a fall day, from mid-morning to mid-afternoon. The goal was to identify the presence of individual VOCs and determine how the VOC levels changed over time and in response to temperature variances within the passenger compartment. The summer temperatures inside the passenger compartment ranged from 115 degrees F to 123 degree F and the fall temperatures ranged from 109 degree F to 121 degrees F (Overton and Manura 1999).

More than 100 VOCs were identified. The air sample collected on the summer day in mid-morning contained the aromatic compound toluene, along with many straight and branched chain hydrocarbons, which may have emitted from the car's interior, but are also common by-products of gasoline and exhaust fumes. Siloxanes also were detected. These compounds are found in cleaning and lubricating products (Overton and Manura 1999).

As the temperature increased, the concentrations of these compounds also increased. Styrene, numerous substituted benzenes and the anti-oxidant compound BHT, which had not be identified in the sample taken earlier in the day, appeared. These benzene derivatives are common in gasoline, paints and carpeting and BHT is common in treatments for leather and vinyl. Styrene derives from styrene-butadiene-rubber latex glue and is used in the manufacturing of carpet. Phenol, a general disinfectant, and 1-methyl-2-pyrrolidinone, an industrial solvent for polymers and petroleum processing, were found in the sample taken during the hottest part of the day (Overton and Manura 1999).

After two months, the VOC concentrations significantly decreased. Styrene, phenol and 1-methyl-2-pyrrolidinone, and BHT were not detected, and the number of benzene derivatives was greatly reduced. The aromatic compound, benzene, and numerous flavor and fragrance compounds, such as hexanal, octanal, nonanal and other aldehydes derivatives, were found.

As the temperature increased, so did the VOC levels. The air sample taken in the cooler part of day (mid-afternoon) showed that the concentration of these compounds had reduced. These results suggest that VOC emissions decrease in a new car over time but still remain temperature dependent (Overton and Manura 1999).

A Japanese study identified 162 individual VOCs, involving many aliphatic hydrocarbons and aromatic hydrocarbons, and measured TVOC concentrations in the interior of a new Japanese car for three years after the car's delivery. High concentrations of n-nonane (458 μg/m^3 on the day following delivery), n-decane (1,301 μg/m^3), n-undecane (1,616 μg/m^3), n-dodecane (716 μg/m^3), n-tridecane (320 μg/m^3), 1-hexadecene (768 μg/m^3), ethylbenzene (361 μg/m^3), xylene (4,003 μg/m^3) and 2,2′-azobis (isobutyronitrile) (429 μg/m^3) were detected, and the TVOC, excluding formaldehyde, was approximately 14,000 ug/m^3 on the day after the delivery (Yoshida and Matsunaga 2006).

The concentrations of most of the compounds decreased with time, but increased with a rise of the interior temperature. During the three-year study, the TVOC concentrations in summer exceeded the indoor guideline value (300 μg/m^3) proposed by Seifert (1995). The main factors affecting the interior concentrations of most compounds were the interior temperature and the number of days after delivery (Yoshida and Matsunaga 2006).

The presence of PBDEs, used in flame retardants, and phthalates, used to soften plastics, also appear in high concentrations in new car interiors. These compounds have been linked to birth defects, impaired learning, liver toxicity, premature births and early puberty in laboratory animals (The Ecology Center 2006).

Investigators from The Ecology Center in Ann Arbor, Michigan collected windshield film and dust samples from 133 randomly selected 2000 to 2005 model cars, manufactured by 11 leading car manufacturers. Table 2 summarizes the results.

Table 2. Ranking of vehicles by company for windshield film concentration of PBDEs, phthalates

Auto Company (number of vehicles Sampled)	Total PBDEs (μg/m^3)	Auto Company (number of vehicles sampled)	Total Phthalates (μg/m^3)
Hyundai (6)	0.054	Volvo (10)	3
Volvo (10)	0.152	BMW (7)	3
BMW (7)	0.178	VW (8)	4
Honda USA (10)	0.193	General Motors (10)	5
Ford (10)	0.280	Toyota USA (10)	6
General Motors (10)	0.301	Honda USA (10)	6
Toyota Import (8)	0.323	Mercedes (8)	6
Honda Import (8)	0.351	Honda Import (8)	7
VW (8)	0.594	Subaru (6)	7
Subaru (6)	0.744	Chrysler (10)	7
Toyota USA (10)	0.936	Toyota Import (8)	8
Chrysler (10)	1.021	Ford (10)	10
Mercedes (8)	1.772	Hyundai (6)	24

Total PBDE levels found in windshield film was 10 times higher and up to 5 times higher in dust taken from car interiors than was found in homes and offices (The Ecology Center 2006). From these results, The Ecology Center investigators concluded, “Assuming inhalation of dust is the primary route of exposure, exposure to PDBEs during a 90-minute drive is equivalent to the exposure from eight (8) hours at work. Occupations requiring workers to spend all or most of their day in a vehicle could result in up to five (5) times the exposure as non-driving occupations” (The Ecology Center 2006).

While the data varies from one study to another, the results clearly demonstrate that interiors of new cars emit very high levels of VOCs, PBDEs and phthalates, which are known to cause a variety of health problems in some people. The amount and type of VOCs differed depending on the make of the car, how old the car was at the time of the air samples were taken and the types of products used.

Japanese Auto Makers Lead the Way to Reduce Indoor Air Toxins in New Car Interiors

Although some automakers are making an effort to reduce the amount of air toxins in new cars, Japanese manufacturers have become the first to set an industry-wide goal of reducing VOCs in passenger compartments. Specifically, they agreed to cut levels of 13 VOCs, including styrene and formaldehyde, by 2007 to match Japanese Ministry of Health, Labor and Welfare requirements for homes. The Japanese Automobile Manufacturers Association initiated the drive in early 2005 after the test of some models failed to meet government guidelines (Greimel 2003, Japan for Sustainability 2005).

Toyota, Nissan, Honda, Mitsubishi and Mazda already have cars on the market that comply with these guidelines and tout lower VOCs levels as a key selling point. Examples of the steps these manufacturers have taken include Nissan changing its seats, door trim, carpets and adhesives; Honda adding an air-conditioning filter to absorb some of the VOCs; Toyota revamping a truck lining; and Mazda focusing on new adhesives. These cars primarily are built in Japan for the domestic market and export. Plans to include models built elsewhere, such as the US, are still under consideration (Greimel 2003).

By and large, US car manufacturers have not yet taken up the charge and are at risk for losing even more market share to the Japanese as consumers become more aware of the dangers posed by exposure to VOCs, PBDEs and phthalates and select car models that have lower emission levels.

Efforts to date include the Ford Focus C-Max becoming the world’s first vehicle to receive the TÜV Rhineland Group’s Allergy Tested Interior certification, which requires TÜV experts to evaluate more than 100 different materials and components along with the vehicle’s interior air quality. During the development of the Ford Focus C-Max, all passenger compartment materials underwent rigorous testing by Ford, TÜV and The British Allergy Foundation to ensure that the potential for allergic reactions to these materials were minimized. Testing included dermatological tests and indoor air quality analysis for VOCs and other compounds. In addition, the car was designed to keep the passenger compartment as free from outdoor contaminants as possible (Ford 2004).

Other efforts include General Motors becoming the first automaker to require that its suppliers eliminate polyvinyl chloride (PVC) from interior panels. Volvo also has conducted tests with the goal of reducing TVOC compounds by one-half in its new V70 and S80 models (Environmental News Network 2001). Volvo also prohibits the use of three types of phthalates and all types of

PBDEs. In addition, Ford reports that it has eliminated the use of PBDEs from interior components that may come in contact with vehicle occupants, and Honda has eliminated most of the phthalate-containing PVC, also used to make seat fabrics, body sealers and interior trim, from its vehicles.

Legislation is pending in a number of US states to ban the use of PBDEs in the automotive industry (The Ecology Center 2006). For more information about PBDEs and indoor environments, see *PBDE Flame Retardants and Indoor Environments: Where There's Smoke, There's Fire?*, which is available free on the AQS Aerias IAQ Resource Center website at www.aerias.org.

Tips for Consumers

Exposure to VOCs, PBDEs and phthalates does not automatically mean adverse health effects will occur. There are many factors that determine if new car owners and people riding in those cars may become ill from exposure, including:

- The concentration and amount of the specific compound as well as its ability to evaporate into the air
- Personal characteristics, such as age, gender, weight and general health status
- Method of exposure – inhaled, ingested or direct contact with the skin
- Exposure to one or more individual VOCs or VOC combinations that create another compound
- Length of time of exposure

Best advice is to make sure the car interior is well ventilated during the first six months of ownership, including bringing in fresh air and ensure it circulates and/or driving with the windows down. Another step consumers can take is to insist car manufacturers take necessary steps to reduce or eliminate where possible VOCs, PBDEs and phthalates in new cars. Car manufacturers will respond if they perceive there is a market advantage to do so.

Tips for Car Manufacturers

Car manufacturers in the US are not without resources and help for addressing this serious issue and making sure they do not get left behind as the Japanese automakers speed ahead.

Air Quality Sciences, Inc. (AQS) offers a test methodology comparable to Europe's requirements VDA 276, "Determination of Organic Substances as Emitted from Automotive Interior Products." Testing is conducted in a controlled environmental chamber following ASTM D 5116 and the European ECA Report # 8. Test conditions are 65 degrees C and 0.4 air changes per hour and measurements are made for VOCs, aldehydes, amines, and phthalates. Results are reported in emission rate or mass of chemical emitted per square area of the product per hour or $\mu g/m^2 \cdot hr$. Various automotive companies use the test results to determine acceptability of products. The test results are not applicable for estimating concentrations that are expected to be found in a passenger compartment of a vehicle at stand still, vehicle operation or other form of operation.

For those manufacturers or suppliers who wish to determine exposure concentrations for risk evaluations, AQS offers testing at elevated temperature (65 degrees C) or room temperature (23 degrees C). Emission reports will be modeled to exposure levels of pollutants based on vehicle characteristics and material usage.

For More Information

Air Quality Sciences stands ready to partner with the automotive industry to create and maintain healthy indoor environments in new cars. Air Quality Sciences also employs experts who can help manufacturers modify their product formulations to be the best performers while lowering VOC emissions.

Visit us at www.aqs.com to learn more about how environmental chamber testing can help you, or call us at (770) 933-0638 and ask for Product Evaluations to order the analysis. Also visit the AQS Aerias IAQ Resource Center to learn more about VOCs and other indoor contaminants. Aerias may be accessed from the AQS website or at www.aerias.org. For a listing of products that are certified to emit low levels of VOCs, visit the GREENGUARD Environmental Institute site at www.greenguard.org.

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