Cleaning Products & Processes:
Partnering for Healthier Indoor Environments

A number of studies in recent years have confirmed that dust control and deep cleaning are effective methods for reducing the level of viruses, bacteria, particulates, endotoxins, molds and allergens in indoor environments (Kildesø and Schneider 2000, University of Tennessee Center for Clean Products and Clean Technologies 2000 as reported in Culver et al 2002). Because these indoor environmental pollutants can make people sick or trigger allergy and asthma attacks, these findings are very good news. Other studies, however, have demonstrated that the very products and processes that are used to keep indoor environments clean also may contribute to indoor pollution (Rumchv et al 2004; Shendell et al 2004; Zock et al 2001; Wolkoff et al 1998). In many cases, volatile organic compounds (VOCs) emissions from cleaning products are the primary cause of concern.

In response, the cleaning industry has made significant strides in its commitment to create and responsibly use and depose of cleaning products to protect both the indoor and outdoor environments. States, such as Connecticut, Massachusetts, Minnesota, New York, Pennsylvania, Vermont and Washington, and cities, such as Seattle, Washington, and Santa Monica and San Francisco in California, also recognize the benefits of using "green" or environmentally friendly cleaning products and are mandating their use in state buildings and public schools (Doling 2005). But more needs to be done to reduce the level of VOCs emissions from cleaning products and processes in indoor environments, even those products deemed environmentally friendly. This article reviews the challenges and opportunities for the cleaning industry to formulate and market low-emitting products.

VOCs in Indoor Environments: Numbers Speak Volumes

Volatile organic compounds are prevalent in indoor environments, with as much 100 to 1,000 different VOCs in the air where people can easily inhale them. Some VOCs can cause eye, nose and throat irritation; cough; headache; general flu-like illnesses; skin irritation; and some can cause cancer. Others produce odors that may be objectionable.

Air Quality Sciences (AQS) has tested the indoor air in hundreds of offices, schools and homes. The results of these studies have confirmed the potential for high levels of VOCs. They also have identified numerous VOCs associated with cleaning products and processes, including:

- Terpenes associated with fragrances
- Hydrocarbons, glycols, and glycol ethers associated with solvents
- Alcohols and aldehydes associated with disinfectants
- Chlorinated hydrocarbons associated with spot cleaners, degreasers and disinfectants
- Light hydrocarbon gases associated with aerosols

The following table (Table 1) lists the 25 most common VOCs found in these indoor environments, along with the types of cleaning products in which they are found.

Table 1. Top 25 Most Common VOCs in Indoor Environments

VOC	Types/Use of Products
1,4 dioxane	Spot removers
Acetaldehyde	Fragrance/disinfectants
Acetic acid esters	Surface cleaners
Acetone	Surface cleaners
Butoxyethanol	Surface cleaners
Butyl acetate	Surface cleaners/fragrances
C_6 - C_{10} substituted alkanes	All cleaners/polishers/waxes
Dichlorobenzene	Deodorizers
Dipropylene glycol	Surface cleaners
Ethanol	Disinfectants
Formaldehyde	Biocides
Isobutane	Aerosol cleaners
Isobutene	Aerosol cleaners
Isopropanol	Disinfectants
Limonene	Orange fragrance
Methoxyethanol	Surface cleaners
Methoxyethoxyl ethanol	Surface cleaners
Methyl methacrylate	Hard surface cleaner
Naphthalene	Disinfectants/moth repellants
Phenol	Disinfectants
Pinene	Pine fragrance
Propylene glycol	Surface cleaners/aerosols
Siloxanes	Waxes/polishes
Tetrachloroethylene	Dry cleaners
Trichloroethylene	Degreasers/spot removers

The total VOC levels (TVOC) in these environments ranged from 40 µg/m³ to 18,000 µg/m³ (micrograms per cubic meter) within two hours of certain cleaning processes, which is up to 36 times higher than the acceptable value (500 µg/m^3 or 0.5 mg/m^3) for VOC emissions from cleaning products, established by the GREENGUARD Environmental Institute. Results from carpet cleaning studies have indicated that VOC emissions may vary from 20 µg/m³ to 12,000

µg/m³, and cleaning of hard surface flooring may lead to VOC levels of 100 µg/m³ to 25,000 µg/m³. Numerous studies have found that individual VOCs and mixtures of VOCs can lead to progressive eye, nose and throat irritation (Mølhave 2000, Otto 1990).

Total volatile organic compound levels are usually compared against the following guide (Table 2) to determine potential health impacts (Mølhave 1986).

Table 2. 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

Reducing the level of VOCs is very important in all indoor environments. Children breathe in more air with respect to their body mass than adults and thus have greater exposure to indoor environmental pollutants, minimizing VOCs in homes and schools is vital. Exposure to VOCs in offices and other business establishments can cause building occupants to feel uncomfortable, distracted or sick to the point that it interferes with their ability to do their work or reduces their motivation to work (Heerwagen et al). Missed work days or days with reduced activity can cost businesses billions of dollars in lost productivity (Dixon 1985, Fisk 2000, AAAAI 2005).

Indoor Air Chemistry: A Complicated Business

The complexity of indoor air presents a difficult challenge for creating and responsibly using cleaning products that emit low VOCs. Interactions and reactions among indoor air constituents are occurring constantly, which makes it very difficult for purchasers and users of cleaning products to manage IAQ and for manufacturers to create and verify that their products have no or low impact.

Although it is invisible to the naked eye, indoor air is a very crowded and intricate place, full of chemicals; particles; viruses and bacteria; allergens and endotoxins; microscopic organisms such as dust mites; water vapor molecules (moisture); dust, and mold hyphae and spores to name a few examples. Complicating matters is the potential for interactions of VOCs with other chemical compounds to form a third compound that also may be a threat. As a result, even though the concentrations of individual VOCs may be well below odor thresholds or known toxic levels, their occurrence in complex mixtures may lead to perceived poor indoor air quality or irritation among those exposed.

For example, d-limonene and other terpene compounds, used in polishes, scented deodorizers, cigarettes, fabrics and fabric softeners, can readily react with fairly common and low concentrations of ozone, brought in from the outdoors or produced by ionizing air cleaners. This reaction creates aldehydes and ultrafine particles, which can be irritating to building occupants (Sarwar et al 2002; Weschler and Shields 1999; Wolkoff et al 2000, Apte and Erdmann 2002).

The results from another study demonstrated that a mopping agent containing terpene generated vast numbers of ultrafine particles in a reaction with ozone. The results also showed that 10 minutes of mopping with this agent influenced indoor particle concentration for more than 8 hours (Long et al 2000).

VOC Emissions Pollute; Not VOC Content

Another challenge for formulating and using low-emitting cleaning products is many cleaning products, even those certified as "green" or environmentally friendly, are rated by their VOC content not by their VOC emissions. Measuring VOCs by weight or content (usually measured as grams per liter minus water) does not give a clear picture of how much of a particular VOC or the total amount of all VOCs (TVOC) from a product may be getting into the air. Nor does it give an accurate picture of how the VOCs emissions from a product will affect the total VOCs in the area in which it is being used. The only way to be sure a product emits low VOCs is to actually measure VOC emissions (usually measured as micrograms per square meter per hour). It is the VOC emissions that contribute to indoor air pollution, not the VOC content.

This is especially critical with cleaning products as potential exposures are directly related to how a product is used. A product may have 10 percent VOCs by weight, which may be low enough to classify it as "green" or environmentally friendly. But, if that product is packaged as an aerosol, it will atomize the VOC particles during use, which increases the potential for exposure. Atomized particles are smaller and lighter, which means they can be inhaled more deeply into the lung, stay suspended longer in the air than larger, heavier particles, and can travel around an indoor environment easier via the heating, ventilating and air-conditioning system. If this same product is delivered using a trigger sprayer, course mist, stream or in a bucket, the risk for exposure diminishes as the particles become progressively larger and heavier and will fall to the ground more rapidly than smaller, lighter particles (Ashkin 2005).

Cleaning industry expert, Stephen Ashkin, president of The Ashkin Group, agrees that measuring VOCs by weight is not optimal, but he is quick to point out that the industry is making great strides in getting more manufacturers on board with the "green" movement. Manufacturers also are responding to the greater demand for "green" products (Ashkin 2005).

"A key factor for growing this demand is to make it easy for purchasers to sort through various product claims and make purchasing decisions. Third-party certifications serve to reassure purchasers and users that the certified products adhere to a set specification for VOCs and that the product is environmentally friendly throughout its life cycle," he said. "Going forward, it would be ideal to certify cleaning products based on VOC emissions, if it can be done cost-effectively, a key concern for manufacturers" (Ashkin 2005).

Going to the Next Level Through Technology Leadership

Manufacturers, building owners, facility managers and commercial cleaning companies have made significant and commendable progress in recent years in their efforts to maintain healthier indoor environments through environmentally friendly cleaning products and deep cleaning processes. The cleaning industry, however, is still at risk for product liability and personal injury litigation associated with exposures to VOCs. In addition, government mandates, market pressures from foreign competitors and a growing awareness of the connection between VOC emissions and adverse health impacts means it is no longer sufficient to just monitor VOC content.

To meet market demand and reduce product liability risks, product manufacturers will increasingly need to demonstrate their technology leadership by going to the next level, namely test and monitor VOC emissions to ensure their products emit low levels of VOCs and potentially reformulate those products that do not comply with testing limits.

The most reliable and scientifically proven way to test for VOC emissions is by using environmental chamber technology (ECT). This method allows a product to produce emissions similar to the way the product would emit in a home, office or school. The collected data is then mathematically modeled to determine exposure concentrations produced by product application in many different indoor environments.

Air Quality Sciences, Inc. (AQS) pioneered environmental chamber testing technology more than 15 years ago and actively participated in establishing the methodology used to test products. This testing methodology was further developed by consensus during an official dialogue among various stakeholders and the US Environmental Protection Agency and has been adopted by ASTM International as D 5116-97, Standard *Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products*, and D 6670-01, *Standard Practice for Full-Scale Chamber Determination of Volatile Organic Emissions from Indoor Materials/Products*. The GREENGUARD Environmental Institute employs this protocol in its certification program for cleaning systems.

Those who embrace a strategy of VOC emissions testing and monitoring and/or responsibly using products that are certified as low emitting (as opposed to low VOC content) will realize major benefits, including:

- Increased goodwill and positive PR associated with industry leadership in addressing public health issues
- Reduced risk of product liability lawsuits
- Fewer product-related odor and irritation complaints from building occupants

AQS stands ready to partner with the cleaning industry to create and maintain healthy indoor enviornments by offering the most complete and most sensitive testing of cleaning products. AQS also employs experts who can help manufacturers modify their product formulations to be the best performers and the best at protecting the indoor environment and building occupants.

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 polluntants. 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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