VOLATILE VINYL

The New Shower Curtain's Chemical Smell

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Center for Health, Environment and Justice

CHEJ

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About the Center for Health, Environment and Justice

CHEJ mentors a movement building healthier communities by empowering people to prevent harm through programs focusing on different types of environmental health threats. CHEJ works with communities to empower groups by providing the tools, direction, and encouragement they need to advocate for human health, to prevent harm and to work towards environmental integrity. Following her successful effort to prevent further harm for families living in contaminated Love Canal, Lois Gibbs founded CHEJ to continue the journey. CHEJ has assisted over 10,000 groups nationwide.

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** Organizations listed for identification purposes only.*

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Executive Summary

New laboratory tests reveal the familiar "new shower curtain smell" may be toxic to our health. Polyvinyl chloride (PVC) plastic shower curtains purchased at Bed Bath & Beyond, Kmart, Sears, Target, and Wal-Mart all contain avoidable toxic chemicals including volatile organic compounds (VOCs), phthalates, organotins and metals. Some of these chemicals are volatile, so they are released into the air inside our homes. This new study reveals that PVC shower curtains can release as many as 108 volatile organic chemicals. Some of these chemicals cause developmental damage as well as damage to the liver and central nervous, respiratory, and reproductive systems. In addition, some chemicals were found in the air 28 days after a PVC shower curtain was unwrapped and hung. This investigation shows that PVC shower curtains are significant contributors to indoor air pollution.

Volatile Vinyl—The New Shower Curtain's Chemical Smell summarizes the results of a two-part laboratory study of the toxic chemicals contained in and released from PVC shower curtains. The first part of this study measured the concentration of chlorine, phthalates, organotins and metals in five PVC shower curtains and VOCs in one curtain purchased at popular retailers. The second part measured the concentrations of VOCs evaporating from a shower curtain in a test chamber over a 28-day period.

Key Findings

PVC Shower Curtains Release Over 100 Chemicals into the Air.

- 108 different volatile organic compounds were released from the shower curtain into the air over the course of the study.
- Toluene, cyclohexanone, methyl isobutyl ketone (MIBK), phenol, and ethylbenzene were detected in the greatest concentrations during the 28-day period. The USEPA also found all of these substances except cyclohexanone in a study of chemicals off-gassing from PVC shower curtains.
- Forty different VOCs were detected in the chamber after 7 days; 16 VOCs were detected after 14 days; 11 after 21 days; and 4 after 28 days.
- The level of Total VOCs measured was over 16 times greater than the recommended guidelines for indoor air quality established by the U.S. Green Building Council and Washington State Indoor Air Quality Program.
- Seven of the chemicals released by the shower curtain are classified as hazardous air pollutants by the United States Environmental Protection Agency (EPA) under the Clean Air Act.
- Two of the chemicals detected, toluene and ethylbenzene, are on California's Proposition 65 list. This law prohibits companies doing business in California from exposing individuals to chemicals known to cause cancer or reproductive toxicity without first giving clear and reasonable warning, and from discharging such chemicals into drinking water.
- VOCs can cause eye, nose, and throat irritation; headaches, loss of coordination; nausea; and damage to the liver, kidney, and the central nervous system. Some VOCs can cause cancer in animals; some are suspected or known to cause cancer in humans.

PVC Shower Curtains Contain High Levels of Phthalates.

- All five curtains tested contained the phthalates di(2-ethyl hexyl) phthalate (DEHP) and diisononyl phthalate (DINP).
- DEHP was the principal phthalate in three

Photo Courtesy of © Stacey Vaeth

of the shower curtains: 25% by weight in the Wal-Mart curtain, 24% in the Bed Bath & Beyond curtain, and 16% in the Target curtain.

- DINP was the principal phthalate in two other curtains: 39% by weight in the Sears curtain and 38% in the Kmart curtain. The Sears curtain also contained a considerable concentration of DEHP (4.8%).

"It is typical for most shower curtains to have a "weird plastic smell" but not like this!! The smell of this curtain was honestly UNDESCRIBABLE! Imagine strong paint, mixed with formaldehyde, bleach, and other pungent chemicals! I still decided to hang it up, but decided to take it down after EVERYONE in the house got nauseous."*

- Some phthalates have been linked to reproductive problems including shorter pregnancy duration and premature breast development in girls and sperm damage and impaired reproductive development in males.
- Since phthalates are not chemically bound to the shower curtain, they can easily migrate from within the curtain to its surface. They may slowly evaporate into the surrounding air and eventually cling to household dust.

PVC Shower Curtains Contain High Levels of Volatile Organic Compounds.

- Twenty-seven VOCs were detected in the Wal-Mart shower curtain at varying levels. Toluene, 2-butanone, and methyl isobutyl ketone (MIBK) were found at the highest concentrations. Other VOCs were found at significant, but lower, levels including ethylenzene, m/p-xylene, and o-xylene.
- The concentration of Total VOCs in the Wal-Mart shower curtain was estimated at 20,000 parts per billion (ppb). This concentration was so high that the analytical equipment was saturated, halting further chemical analysis.

PVC Shower Curtains Contain Organotins.

- The organotins dibutyl tin and monobutyl tin were found in 3 of 5 or 60% of the shower curtains tested (the Wal-Mart, Kmart, and Target curtains).
- Some organotins affect the central nervous system, skin, liver, immune system and reproductive system.
- Since the organotins are not chemically bound to the shower curtain, they can easily migrate from within the curtain to its surface. From there, some organotins are likely to evaporate into the air, but this matter needs to be further explored.

PVC Shower Curtains Contain Lead, Cadmium and Other Metals.

Each of the five shower curtains tested contained one or more of these metals: Lead, cadmium, mercury and chromium.

Heat and Humidity Can Increase the Release of Chemicals from Shower Curtains.

- This testing did not replicate temperature and humidity conditions typically found in a shower which would likely increase the concentrations of volatile pollutants released from a PVC curtain into the air of a bathroom.
- Therefore, the concentrations of these chemicals are likely to be greater during and after a shower than those reported here.

* This quote is excerpted from Target customer complaints, posted on Target.com, about odors from PVC shower curtains. Other quotes from the website are interspersed throughout the report. In response, Target has offered more PVC-free shower curtains.

Leading Retailers are Phasing out PVC Shower Curtains.

- CHEJ contacted leading retailers around the world to determine whether or not companies have developed plans to phase out PVC shower curtains.
- Bed Bath & Beyond, IKEA, JC Penney, Macys, Marks and Spencer, Sears Holdings (Sears and Kmart) and Target have all developed plans to offer more PVC-free shower curtains, but not all of these retailers have set 100% PVC-free phase-out plans and goals.
- So far, the retailers that have set these more ambitious goals are IKEA and Marks and Spencer.

No Federal Standards Exist to Prevent Indoor Air Pollution due to Toxic Chemical Releases from Products.

- This investigation highlights the fact that no federal agency has the legal authority to regulate consumer products that release toxic chemicals such as VOCs into the air inside our homes.
- Neither the U.S. Environmental Protection Agency (USEPA), which regulates the ambient air, nor the Consumer Product Safety Commission, which regulates chemicals in consumer products, can do this.
- Congress needs to step in and reform America's outdated chemical policies.

Corporate and Government Policy Recommendations.

Based on the results of this study, it is critical for companies and government to implement an immediate phase-out of PVC in all shower curtains. We recommend the following actions to prevent harm and halt toxic air pollution in people's homes.

1. Manufacturers and retailers should implement the following actions.

- Phase out PVC shower curtains and switch to safer products such as organic cotton shower curtains.
- Label the material content of shower curtains so that consumers can easily identify safer products. Shower curtains without PVC should be labeled "PVC-free." By requiring all PVC products to be labeled, consumers can readily identify where PVC is used in the home.
- Label PVC shower curtains with warnings of the chemicals present in the new shower curtain smell.

2. Governments at all levels should implement the following actions.

- Act quickly to adopt policies to protect consumers and ban the use of PVC in shower curtains.

Photo : © iStockphoto

- Adopt PVC-free procurement policies to help build markets for safer products.
- Require warning labels on PVC shower curtains. Warnings should alert consumers to the fact that over 100 chemicals can be released during use in the home. Labeling would also encourage product manufacturers to switch to safer products to avoid labeling requirements.

"I hung this shower curtain and the smell was so overwhelming it gave me a headache. I gave it a chance but ended up getting up at 2 in the morning to take it down, it was that bad. It smelled up my entire house. I had to return it and purchased the fabric one online."

- Require that PVC shower curtains and other PVC products be collected and diverted from burn barrels and incinerators to reduce the formation of dioxins and furans; PVC should be treated as a hazardous material. As an interim measure, PVC could be disposed of in "secure" triple-lined hazardous waste landfills.
- Conduct a public campaign to educate consumers about the risks posed by PVC products such as shower curtains in the home.

3. The Consumer Product Safety Commission should recall PVC shower curtains on the market and require manufacturers to switch to safer products.

4. Federal policymakers should reform America's outdated chemical policies that are failing to protect families from toxic chemicals already on the market that are released in our homes. The federal law regulating industrial chemicals, the Toxic Substances Control Act (TSCA), is 30 years old, outdated, and simply does not work to protect people and the environment. PVC in shower curtains is one of many examples of the need to reform federal law to protect consumers. TSCA must be amended to:

- Require complete and credible health and safety data on chemicals and make this data publicly available;
- Require companies that legally manufacture or import chemicals into the U.S. to provide minimum toxicity data;
- Require product manufacturers to test for and publicly disclose the chemical contents of their products;
- Prohibit the use of dangerous chemicals such as carcinogens, mutagens, reproductive toxicants, and persistent bioaccumulative toxic (PBT) chemicals in products, especially those found in the home and targeted at infants and children, or that accumulate in our bodies;
- Create health-based standards for VOCs and other chemicals in the air in consumers' homes;
- Provide consumers with information to make safer purchases by requiring the disclosure of chemical information and warning labels; and
- Provide information, funding, research, and technical resources in "green chemistry" to businesses so they can make products such as shower curtains safe for consumers with incentives to invest in green economic development to spur innovation in safer products.

5. Recommendations for Consumers.

- Avoid shower curtains made with PVC, as well as other PVC products, especially those that are flexible. These products are not always labeled although some may be labeled as "vinyl" or "PVC." Do not buy shower curtains that are not labeled.
- Purchase PVC-free shower curtains made out of safer materials including organic cotton.

CHAPTER 1
Introduction

When you open a new PVC shower curtain, you're immediately hit with a strong chemical odor which may persist in your home for days, weeks, or even months. This "new shower curtain smell" may even make you feel nauseous, give you a headache, or make you feel sick. To determine which chemicals are causing this intense odor, we commissioned two scientific laboratories to put PVC shower curtains to the test.

Polyvinyl chloride, commonly known as "PVC" or "vinyl," is the second largest commodity plastic in production in the world today. An estimated 59 billion pounds were produced worldwide in 2002 (CEH 2003). Nearly 15 billion pounds are produced annually in the U.S. (VI 2008). PVC is used in a wide range of products including pipes and tubing, construction materials, product packaging, electrical wiring, children's toys, credit cards, clothing, carpeting, furniture, flooring, automotive seats, garden hoses, cellular phones, computer parts, office supplies, siding on our homes, roofing and other building materials (Ackerman 2006).

While PVC plastic is quite common, most people are not aware that it poses serious environmental and health threats at all stages of its lifecycle. By understanding the harm posed by PVC in consumer products, during production, use and disposal, we can spur political, business, and consumer action to phase out this toxic and problematic material. Consumers can do their part by choosing not to buy products made from PVC, such as shower curtains, or packaged in PVC, and by letting companies and elected officials know that they want safer products.

Product testing has identified many vinyl products that contain and leach toxic additives such as phthalates, lead, cadmium, and organotins. Such testing has been successfully used to effect change in the sale of PVC and other chemicals found in consumer products. For example, the Environmental Working Group tested wooden playground equipment to demonstrate the leaching of arsenic (Sharp 2001). This information combined with the sustained efforts of the Healthy Building Network and the Center for Environmental Health successfully shifted the $4 billion pressure-treated wood market. The Campaign for Safe Cosmetics tested cosmetics for toxic additives, which has encouraged many companies to sign the "Compact for Safe Cosmetics."

This report focuses on one common consumer product made from PVC—shower curtains—to highlight the health and environmental concerns related to PVC products in our homes. American consumers need to be aware of the toxic components of this poison plastic, and ask why this material is used in products that enter our homes, contaminating the air we breathe.

We can prevent harm from PVC by replacing it with safer available products and materials. Consumer demand for safer products helps shift the market towards healthy products. When we avoid purchasing PVC products, we send a clear message to the chemical industry and government that toxic materials like PVC need to be phased out. We hope you find the information in this report useful and informative, and that you will join us in our efforts to build a healthy toxic-free future for all.

CHAPTER 2

The Dangers of PVC, the Poison Plastic

Polyvinyl chloride (PVC) plastic poses serious environmental and health threats at all stages of its lifecycle: from manufacturing to use to disposal. Some PVC products pose direct health risks to consumers, though the hazards most often associated with PVC occur during its production and disposal (Thornton 2002).

The Production of PVC Shower Curtains Involves Cancer-Causing Chemicals

PVC shower curtains are made from toxic chemicals. Three chemicals are at the core of PVC production: chlorine gas is used to produce ethylene dichloride (EDC), which is then converted into vinyl chloride monomer (VCM) which is then converted into PVC (Thornton 2002). Both VCM and EDC are extremely hazardous. Vinyl chloride, the key building block of PVC, causes a rare form of liver cancer, and damages the liver and central nervous system (Kielhorn 2000). Vinyl chloride is one of the few chemicals the U.S. EPA classifies as a *known human carcinogen* (ATSDR 2006). EDC is a probable human carcinogen that also affects the central nervous system and damages the liver (USEPA 2007). In addition, mercury emissions are another environmental and public health concern associated with PVC production (Steingraber 2004, USEPA 2003).

PVC Leads to Dioxin Formation

The formation of dioxin is a major concern with PVC's lifecycle. When PVC is manufactured or burned as a waste material, numerous dioxins are formed and released into the air or water. The term 'dioxin' refers to a family of chemicals that are unintentionally made. They are generated as by-products during production and disposal of chlorinated compounds including PVC. Dioxins are a highly toxic group of chemicals that build up in the food chain, cause cancer and can harm the immune and reproductive systems (USDHHS 2002, WHO 1997, Birnbaum and Farland 2003). The toxicity of dioxins is of such concern that they have been targeted for

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Photo Courtesy of © Les Stone/Greenpeace

David and Diane Prince in front of their former home in Mossville, LA near the front gate of the Condea Vista and Georgia Gulf PVC chemical plants (see box on page 12).

global phase out by the Stockholm Convention on Persistent Organic Pollutants (UNEP 2000). Dioxins have also been targeted for virtual elimination in the Great Lakes through the U.S. and Canadian Great Lakes Binational Toxics Strategy (USEPA 2006).

PVC is Harmful to Workers

Studies have documented links between working in PVC facilities and the increased likelihood of developing diseases including angiosarcoma, a rare form of liver cancer (Creech 1974), brain cancer (Lewis 2002), lung and liver cancer (Mastrangelo 2003, Gennaro 2003), lymphomas, leukemia, and liver cirrhosis (Gennaro 2003). Workplace exposures in PVC facilities have been significantly reduced from the levels of the 1960s, however there is no threshold below which vinyl chloride monomer (VCM), a major constituent in PVC production, does not increase the risk of cancer. Thus, current exposures in the U.S. continue to pose cancer hazards to workers. Furthermore, occupational exposure to VCM remains high in some facilities in Eastern Europe and Asia (Thornton 2002). There is also evidence of increased risk of developing cancer for workers exposed to dioxins in PVC plants (Steenland 2004, Hardell 2003). In addition to chronic diseases, PVC workers face deadly hazards from accidents and explosions on the job at PVC manufacturing plants (Steingraber 2005, USCSB 2007).

PVC Pollutes the Air and Groundwater of Surrounding Communities

PVC chemical plants are often located in or near low-income neighborhoods and communities of color, such as Mossville, Louisiana (see box, page 12), making the production of PVC a major environmental justice concern. Reveilletown, Louisiana was once a small African-American town adjacent to a PVC facility owned by Georgia-Gulf. In the 1980s, after a groundwater toxic plume of vinyl chloride began to seep under homes, Georgia-Gulf agreed to permanently evacuate the entire community of one hundred and six residents (UCC CRJ 1998). In Pottstown, Pennsylvania, chemical waste dumped in lagoons at the OxyChem PVC plant contaminated groundwater and is now targeted for cleanup under the federal Superfund program (ACE 2008). In Point Comfort, Texas, vinyl chloride was discovered in wells near a Formosa PVC chemical plant, and the company had to spend one million dollars cleaning up contaminated groundwater (Lewis 1999).

PVC: Second Largest User of Mercury Globally

Mercury is used to produce chlorine gas globally. In China and Russia, mercury is also used to make vinyl chloride monomer, the basic building block of PVC (NRDC 2006). This use accounts for an astonishing 20% of global mercury consumption (700 tons), the second largest sector globally (Bailey 2007). Mercury is a potent neurological and reproductive toxin that accumulates primarily as methyl mercury in aquatic food chains (NAS 2000). The PVC industry's use of mercury has been increasing in recent years despite the fact that the dangers of mercury are well-known. In 2002, the Chinese PVC industry used 354 tons of mercury (NRDC 2006). Within two years, that had increased to 610 tons of mercury, growing at an annual rate of 31.4%. It's been estimated that mercury usage will continue to increase to over 1,000 tons by 2010 (NRDC 2006). Assuming PVC

CASE STUDY

Mossville, Louisiana—PVC and Environmental Racism

Mossville, Louisiana is a small African American community nestled amid an alarming number of PVC production facilities. It is the vinyl manufacturing capital of America, as the Calcasieu Parish region, is home to more PVC chemical plants than anywhere else in the country. A 1999 U.S. Environmental Protection Agency (EPA) study found vinyl chloride levels in ambient air greater than 100 times the state air quality standard (Subra 2002). In 2001, five international companies located in the parish (Georgia Gulf, Conoco Phillips, Entergy, PPG Industries, and Sasol) reported releasing dioxins, a cancer-causing, highly toxic group of chemicals, according to EPA's Toxics Release Inventory (USEPA 2001). Independent studies confirmed groundwater is threatened by liquid toxic leachate, and there are contaminated fish, vegetables, and fruit in the area (MEAN 2007).

The health and well being of Mossville residents has been hobbled with elevated rates of disease. Studies in 1998 and 2001 by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) found alarming results—residents had more than three times the national average of dioxins in their blood, elevated dioxins in breast milk, and high cancer mortality rates (MEAN 2007). A 1988 university study found Mossville residents were two to three times more likely to suffer from health problems, including a high incidence of ear, nose, and throat illnesses, central nervous system disturbances, and cardiovascular problems, as well as increased skin, digestive, immune, and endocrine disorders (Zilbert 2000).

Ever determined to reclaim their lives, Mossville residents have fought back against the polluters and had real results, including winning relocation for many families due to a 1994 Condea Vista spill of one million pounds of ethylene dichloride that caused well water contamination (LBB 2001). Mossville citizens also successfully advocated at the national level, achieving a 2005 U.S. Court of Appeals decision to change outdated and ineffective EPA emissions standards for vinyl chloride plants (ENS 2005). In 2005, Mossville Environmental Action Now (MEAN) brought the first ever environmental human rights legal challenge against the U.S. Government that is being reviewed by the Inter-American Commission on Human Rights of the Organization of American States. Recently, MEAN compiled data from the USEPA and ATSDR and found 77% of the mixture of dioxin compounds released by the Georgia Gulf PVC plant were the same dioxin compounds that made up 77% of the dioxins detected in the blood of Mossville residents. This finding shows that residents are accumulating the same mixture of dioxin compounds being released from the Georgia Gulf PVC plant and this mixture includes the most toxic forms of dioxin (MEAN 2007).

Photo Courtesy of © Gray Little/Greenpeace

Young residents of Mossville, LA play near the Condea Vista and Georgia Gulf PVC chemical plants (see box on page 12).

accounts for 40% of the global chlorine production, between chlorine and vinyl chloride monomer production, the PVC industry currently accounts for 27.2% of the world's mercury consumption, the second largest user of mercury in the entire world (Bailey 2007, Thornton 2002).

PVC Production Sites a Target for Terrorists

A 2002 Rand report for the U.S. Air Force identified the transport and storage of chlorine gas as among the top chemical targets for a terrorist attack and cited examples of threats and attacks already carried out around the world (Karasik 2002). As a prime feedstock for PVC, chlorine makes the PVC industry and the trains that deliver the chlorine highly vulnerable to terrorist attacks. Experts predict that as many as 100,000 Americans could be killed or injured in just 30 minutes as a result of a terrorist attack on railways carrying lethal chlorine (Hind 2005). The best security would be to switch to safer materials that don't require chlorine. Since PVC production is the largest single use of chlorine (ATSDR 2007), reducing its use represents the single most important step we can take to reduce the risk of accidental or intentional chlorine disasters.

PVC in Consumer Products

PVC plastic used in consumer products is not a pure material. By the time a product containing PVC reaches your home, a number of chemicals have been added to change its properties to meet different product needs (Thornton 2002, OECD 2004). These additives include stabilizers, such as lead, cadmium, antimony and organotins, plasticizers, such as phthalates, and fillers (CEC 2000, OECD 2004). Many of those additives are not chemically bound to the PVC and can migrate out of the product posing potential hazards to consumers (Thornton 2002). In some cases, these additives can evaporate from the product into your home (CARB 1999, Rudel 2000, Uhde 2001).

CASE STUDY

Detroit, Michigan's Toxic Incinerator

Municipal waste incinerators are significant generators of highly toxic dioxins (USEPA 2006a) and PVC in the waste stream is a major source of the chlorine needed to form dioxins during combustion. Residents of Detroit, Michigan have been waging an epic battle against the city's billion-dollar waste-to-energy incinerator. It is the largest incinerator ever built, with a capacity to burn 4,000 tons of waste per day, including PVC shower curtains and other PVC products. Incinerators are a major source of dioxins, which increase as PVC content in burned waste increases. This facility is also the most expensive of its kind; an initial cost of $440 million has ballooned to an estimated $1 billion due to debt for construction and operation.

The trouble began in 1975 when initial calculations estimated there would be cancer-related deaths 19 times higher than any risk ever approved by the MI Department of Natural Resources. Five years later, numerous violations of pollution regulations caused the state to close the incinerator for 2 years (Morganfield 1990). The incinerator now releases over 25 tons of hazardous air pollutants and 1,800 tons of other pollutants annually, including mercury, lead, and dioxins (Doyle and van Guilder 2002). Because the incinerator is a major source of air pollution, area residents have suffered adverse health effects. Many of the incinerator's pollutants can cause serious respiratory effects and contribute to global warming and acid rain. Hospitalization rates for asthma are highest in the zip code areas located close to the incinerator (Ecology Center 2005).

Community-based, statewide, national and international organizations have strongly advocated for the protection of area residents and closure of the incinerator. Spanning from courtroom legal battles, demonstrations and incinerator blockades, residents have sought and received additional pollution controls for the incinerator, but the real turning point will come when the city makes a decision whether to close the incinerator. Closing could happen as early as July 1, 2009 (van Guilder 2008).

Burning PVC Leads to Dioxin Formation

A major concern about PVC is the formation of dioxins whenever it is burned. This is due to the relationship between PVC, chlorine, and dioxin. PVC is a significant source of the chlorine necessary for dioxin formation during the combustion of municipal and household waste in incinerators, burn barrels, landfills and open dumps (see box, above). The strongest evidence of dioxin formation during combustion comes from laboratory studies showing that PVC content in the waste stream fed to incinerators is linked to elevated levels of dioxins in stack air emissions (Costner 2001, USEPA 2006a)* and in residual incinerator ash (Theisen 1991, Wilken 1994). Dioxins also form when PVC products and materials are burned in accidental building and vehicle fires (USEPA 2006a, IAFF 1995, TNO 1996).

* Numerous studies are discussed in detail in Lester and Belliveau 2004.

Discarding PVC Shower Curtains in Landfills Poses Risks

The land disposal of PVC product waste, especially flexible materials such as shower curtains, also poses environmental and public health risks. As flexible PVC degrades in a landfill, toxic additives leach out of the waste into groundwater, which is especially problematic for unlined landfills (CEC 2000, Mersiowski 1999, ARGUS 2000, AEA 2000). These additives also contribute to the formation of landfill gases (ARGUS 2000), which are formed in municipal waste landfills (ATSDR 2001, USEPA 1995). In addition, there are over 8,400 landfill fires reported every year in the U.S. (FEMA 2002). These fires burn PVC waste and contribute to dioxin formation (USEPA 2006a). Land disposal is the final fate of between 2 and 4 billion pounds of PVC that are discarded every year at some 1,800 municipal waste landfills in the U.S. (Kaufman 2004).

CHAPTER 3

Testing the Chemicals in a PVC Shower Curtain

Study Overview

The first part of the study measured the concentrations of selected hazardous chemicals in five common PVC shower curtains purchased at major retailers. This testing was conducted by Southwest Research Institute (SwRI) in San Antonio, Texas. The substances analyzed for were chlorine, 5 phthalates, 7 organotins, and 14 metals in five PVC curtains, plus 65 volatile organic compounds (VOCs) in one PVC shower curtain. The initial plan was to analyze each of five shower curtains for all of these substances except the metals. However, due to analytical issues resulting from very high levels of VOCs found in the first shower curtain tested, analysis of VOCs was substituted with a metal analysis. The methods and materials used to measure each group of substances are summarized below. The list of specific chemicals measured, the analytical methods used, and additional information are in Appendix B.

Methods and Materials

The Center for Health, Environment and Justice (CHEJ) purchased five unopened PVC shower curtains at Bed Bath & Beyond, Kmart, Sears, Target, and Wal-Mart in New York as shown in Table 1, and shipped them to Southwest Research Institute on September 27, 2006.

Each shower curtain was opened and cut into multiple pieces, approximately 2 x 2 inches in size. The pieces were weighed and the weights recorded as shown in Table 2.

"It smells sort of like gasoline. It stunk up almost my whole house. At first we thought we had a gas leak it was so bad and then realized it was the new shower curtain we put up today...I went back to smell the plastic bag that it comes in and almost got sick. I know shower curtains usually have that new smell, but never have I ever smelled one like this."

Chlorine was measured in all five shower curtain samples using ion chromatography and a modification of American Standard Testing Method (ASTM) D808-05. A duplicate sample was collected and analyzed for one shower curtain (purchased from Bed Bath & Beyond), and a matrix spike was performed.

Volatile Organic Compounds (VOCs) were measured in only one shower curtain, purchased from Wal-Mart. Sample preparation was achieved by leaching the VOCs into heated water with a

TABLE 1 **Shower Curtains Tested**

Retailer Where Curtain Was Purchased	Description of Curtain
Bed Bath & Beyond	Premium Weight Vinyl Shower Curtain Liner, Stall Size, 54"x78"
Kmart	Martha Stewart Everyday Vinyl Shower Curtain, Bath Bliss, 70"x71"
Sears	Whole Home Deluxe Vinyl Stall Liner, 54"x78"
Target	Contemporary Home Shower Curtain, Metro Blocks, 70"x72"
Wal-Mart	HomeTrends Kids Vinyl Shower Curtain, Under the Sea, 70"x72"

TABLE 2 **Size of Samples for Analysis**

Analysis Target	Number of Samples/Curtain	Weight per sample (grams)
Chlorine	1	1
Volatile Organic Compounds	2	5
Phthalates	1	1
Organotins	1	1
Metals	3	1

Photo Courtesy of © Stacey Vaeth

Examples of PVC shower curtains tested for this study.

purge and trap using EPA Method 5035. The 65 target VOCs were determined using a gas chromatograph/mass spectrometer (GC/MS) and EPA Method 8260. Total VOCs were estimated by integrating the area under the entire chromatogram from the Method 8260 analysis, assuming the same response for all compounds as for the internal standard. Due to high levels of some VOCs, additional samples were not analyzed to avoid potential instrument damage. The high levels saturated the column and resulted in a required increase in the planned VOC detection limits for the other shower curtain samples to avoid instrument damage.

Phthalates were measured in all five shower curtain samples. They were extracted using a procedure based on the method described by Shen (2005). Diethyl phthalate (DEP), di-n-butyl phthalate (DBP), butyl benzyl phthalate (BBP), di(2-ethylhexyl) phthalate (DEHP), diisononyl phthalate (DINP), and di-n-nonyl phthalate (DNP) concentrations in the curtains and a solvent blank were determined on an Agilent 6890 gas chromatograph (GC) equipped with a 5973 Mass Selective detector in full scan mode. Di-(2-ethylhexyl) phthalate-d4 was used as the internal standard.

Organotins were measured in all five shower curtain samples. They were extracted using a procedure based on the method described by Dirkx (1994), then cleaned and derivitized as described in Appendix B. Concentrations of monobutyltin, dibutyltin, tributyltin, tetrabutyltin, tricyclyohexyltin, triphenyltin, and di-n-octyltin were determined on an Agilent 6890 GC equipped with a 5973 Mass Selective detector in selected ion monitoring mode. Tributyl phenyltin was used as the internal standard.

Metals were measured in all five shower curtain samples. Three separate 1-gram portions of each curtain were used for the metals analyses. One 1-gram sample was prepared and analyzed for mercury using Cold Vapor Atomic Absorption (CVAA) according to SW-846 Method 7471A. A second 1-gram sample was placed in an open vessel acid digestion with concentrated nitric acid and analyzed for copper and silver. The remaining metals—aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, iron, potassium, magnesium, manganese, sodium, nickel, lead, antimony, selenium, thallium, vanadium and zinc—were determined from an open vessel digestion of a third 1-gram sample with concentrated nitric acid and aqua regia. All metals except mercury were determined by Inductively Coupled Plasma (ICP) using SW-846 Method 6010B. For quality control purposes, one duplicate sample was collected and analyzed for the Bed Bath & Beyond shower curtain.

Test Results

Vinyl shower curtains were analyzed for the presence of chlorine, metals, organotins, phthalates, and volatile organic compounds (VOCs) in the material content. Only one curtain, purchased at Wal-Mart, was analyzed for VOCs due to finding extraordinarily high concentrations that led to laboratory complications (see above for details).

Testing for Chlorine: Identifying PVC

All five shower curtains were tested for chlorine to confirm its presence and the likelihood that the curtains were made out of PVC. The percentage of chlorine ranged from 30.1 to 35.3 percent as shown in Table 3. These values confirm that chlorine was a major chemical component in the shower curtains and PVC was therefore a primary constituent of each shower curtain tested. The chlorine concentration measurements were repeatable, with results of 34.6% and 35.3% obtained from duplicate samples taken from the Bed Bath & Beyond curtain.

"The smell is OVERWHELMING. There's a normal 'shower curtain smell' to every new curtain, but this is completely different. I seriously got sick, and my sinuses were swollen for a week. Most of the day I left the bathroom vent on which helped a lot. But still, house guests could smell it from outside!"

Testing for Volatile Organic Compounds (VOCs): High Concentrations Found

One shower curtain was tested for VOCs and several VOCs were found at very high concentrations as shown in Table 4 (page 18). The testing showed the following results.

- Twenty-seven of 65 VOCs were detected in the Wal-Mart shower curtain at varying levels.
- Toluene, 2-butanone, and methyl isobutyl ketone (MIBK) were found at very high concentrations in the Wal-Mart shower curtain. The estimated concentrations ranged from 1,900 to 5,200 parts per billion (ppb) as shown in Table 4. Two of these same chemicals were also found to be off-gassing in another PVC shower curtain study conducted by the USEPA (Chang 2002).
- Other VOCs were found at substantial, but lower, levels in the Wal-Mart shower curtain, including ethylbenzene, m/p-xylene and o-xylene. The estimated concentrations ranged from 160 to 260 ppb (see Table 4). The USEPA also found high levels of ethylbenzene in their study (Chang 2002).
- The concentration of Total VOCs in the Wal-Mart shower curtain was estimated at 20,000 ppb.

TABLE 3 **Percentage of Chlorine (by weight) in PVC Shower Curtains**

	Bed Bath & Beyond		Kmart	Sears	Target	Wal-Mart
	Sample	Duplicate				
Chlorine	34.6%	35.3%	35.1%	30.1%	31.9%	32.8%

TABLE 4 **Volatile Organic Compounds Detected in PVC Shower Curtain**

Volatile Organic Compound	Concentration (ppb) In Wal-Mart Curtain
2-Butanone	5200^
Toluene	2500^#
Methyl isobutyl ketone (MIBK)	1900^
m/p-Xylene	260^
Ethylbenzene	240^
Cycloheptane	220*
o-Xylene	160^
Decane	82*
Isopropylbenzene	46
Undecane	46*
Heptane, 2,2,4,6, 6-pentamethyl-	37*
1,2,4-Trimethylbenzene	25
1-Hexanol, 2-ethyl-	24*
Trans-decalin, 2-methyl-	18*
Benzene, 1-methyl-2-(1-methylethyl)-	12*
1,3,5-Trimethylbenzene	9
Dodecane	6*
Benzene	5
2-Propenoic acid, 2-methyl-, methyl ester	5*
Methylene chloride	3
Naphthalene	3
Styrene	3
Cyclohexane, methylene-	3*
Acetone	2
p-Isopropyltoluene	2
1-Butanol	2*
1,2,3-Trichlorobenzene	1

Notes: ^ Indicates crude estimated value, due to response exceeding calibration range; # Indicates probable substantial underestimate; * Indicates tentative identification and estimated value.

- Ten other VOCs were found in the Wal-Mart curtain at concentrations ranging from 1 ppb for 1,2,3-trichlorobenzene to 46 ppb for isopropyl benzene and undecane (see Table 4).
- Eleven VOCs were tentatively identified in estimated concentrations ranging from 2 ppb for 1-butanol to 220 ppb for cyclopentane (see Table 4), marked by an asterisk (*). Tentative values were estimates based on the response of the nearest internal standard.
- The concentrations of VOCs exceeded the expected maximum and resulted in saturation of the GC column used in analysis. Further analysis of VOCs using the same procedure was not performed to avoid instrument damage.

Testing for Phthalates: High Concentrations Found

All five shower curtains were tested for phthalates, which were found to be present at varying concentrations in all the curtains as shown in Table 5 (page 19). This testing showed the following results.

- All five shower curtains contained both DEHP and DINP.
- DEHP was the principal phthalate found in three of the shower curtains: 25% by weight in the Wal-Mart curtain, 24% in the Bed Bath & Beyond curtain and 16% in the Target curtain.
- DINP was the principal phthalate found in two curtains: 39% by weight in the Sears curtain and 38% in the Kmart curtain. The Sears curtain also contained a considerable concentration (4.8%) of DEHP.
- DEP, BBP, and DNP were not detected in any of the shower curtains.
- None of the phthalates were detected in the blank sample, indicating there was no laboratory introduction of phthalates for any shower curtain samples.

Testing for Organotins: Found in 60% of Shower Curtains

All five shower curtains were tested for organotins which were found to be present at varying concentrations as shown in Table 6. This testing showed the following results.

- Dibutyl tin and monobutyl tin were found in 3 of the 5 or 60% of the PVC shower curtains tested at concentrations ranging from 0.12 to 3.5 micrograms per gram (μg/g) (see Table 6). These organotins were found in the Wal-Mart, Kmart, and Target shower curtains.
- Tetrabutyl tin, tricyclohexyl tin, triphenyl tin and di-n-octyl tin were not detected in any of the five shower curtains.
- Tributyl tin (TBT) was detected in all five of the shower curtains at concentrations ranging from 0.03 to 0.04 μg/g. However, since TBT was detected at similar levels in the blank sample, this finding indicated a laboratory-introduced contaminant. None of the six other organotins were detected in the blank sample, indicating no laboratory introduction of these six organotins.

"I can't believe they would sell a shower curtain for kids which smells so horrible! I tried airing it out in our garage for a couple of weeks and still it was intolerable. Had to return it despite it being cute."

TABLE 5 **Percentage of Phthalates (by weight) in PVC Shower Curtains**

Phthalate	Bed Bath & Beyond	Kmart	Sears	Target	Wal-Mart
Di(2-ethylhexyl) phthalate (DEHP)	24%	0.14%	4.8%	16%	25%
Diisononyl phthalate (DINP)	0.13%	38%	39%	0.11%	0.10%
Diethyl phthalate (DEP)	ND[1]	ND[1]	ND[1]	ND[1]	ND[1]
Di-n-butyl phthalate (DBP)	ND[2]	ND[2]	ND[2]	ND[2]	ND[2]
Butyl benzyl phthalate (BBP)	ND[2]	ND[2]	ND[2]	ND[2]	ND[2]
Di-n-nonyl phthalate (DNP)	ND[3]	ND[3]	ND[3]	ND[3]	ND[3]

Notes: ND = Not Detected, below the Limit of Detection (LD); Detection Limits differed for each phthalate, and are specified here—
1. LD = 0.25 mg/g; 2. LD = 0.13 mg/g; 3. LD = 0.12 mg/g.

TABLE 6 **Concentrations of Organotins (μg/g) Measured in PVC Shower Curtains**

Organotin Compound	Bed Bath & Beyond	Kmart	Sears	Target	Wal-Mart
Monobutyl tin (MBT)	ND	0.12	ND	0.38	0.15
Dibutyl tin (DBT)	ND	1.4	ND	.81	3.5
Tetrabutyl tin	ND	ND	ND	ND	ND
Tricyclohexyl tin	ND	ND	ND	ND	ND
Triphenyl tin	ND	ND	ND	ND	ND
Di-n-octyl tin	ND	ND	ND	ND	ND

Note: ND = Not Detected, below the Limit of Detection (0.02 μg/g [ppm]).

TABLE 7 **Concentrations of Metals (ppm) in PVC Shower Curtains**

Metal	Bed Bath & Beyond		Kmart	Sears	Target	Wal-Mart
	Sample	Duplicate				
Aluminum	1.3	2.0	138	7.5	64	104
Arsenic	ND	ND	ND	ND	ND	ND
Barium	43	46	42	83	56	77
Cadmium	0.07	0.08	0.59	ND	ND	ND
Calcium	9.7	10.4	7.4	1,440	10.1	36
Chromium	ND	ND	0.22	ND	ND	ND
Cobalt	ND	ND	ND	0.19	ND	ND
Copper	ND	ND	1.6	ND	21.2	18
Iron	1.5	1.5	3.2	3.3	2.9	5.3
Lead	ND	ND	1.2	17.5	ND	ND
Magnesium	ND	ND	ND	6.3	ND	5.6
Mercury	0.0054	0.0054	ND	ND	ND	ND
Sodium	18	18	46	20	33	39
Zinc	36	36	33	13	65	36

Note: ND = Not Detected, below the Limit of Detection (see Appendix B).

Testing for Metals: Found in All Shower Curtains

All five shower curtains were tested for metals and found to contain metals at varying concentrations in all the curtains as shown in Table 7. This testing showed the following results.

- Varying concentrations of different metals were found in all five shower curtains.
- Cadmium was found in the Kmart shower curtain at 0.59 parts per million (ppm) and in the Bed Bath & Beyond shower curtain at 0.07 ppm.
- Chromium was found in the Kmart shower curtain at 0.22 ppm.
- Lead was found in the Sears shower curtain at 17.5 ppm and in the Kmart shower curtain at 1.2 ppm.
- Mercury was found in the Bed Bath & Beyond shower curtain at 0.0054 ppm.
- Aluminum, barium, calcium, iron, sodium and zinc were detected in all five curtains.
- The concentration of metals found in one duplicate sample for the Bed, Bath, and Beyond shower curtain was similar to the original sample.
- All metals measured in the blank sample were below the limit of detection.

CHAPTER 4

Testing the Chemicals Released from a PVC Shower Curtain

Study Overview

This portion of the study measured the concentration of volatile organic compounds (VOCs) evaporating from a PVC shower curtain placed in a small chamber over a 28-day period. This testing was conducted by Air Quality Sciences (AQS) in Marietta, Georgia. The substances analyzed in this phase were VOCs and phthalates. The methods and materials used to measure each group of substances are summarized below. A list of the specific substances measured and the analytical methods are in Appendix C.

Methods and Materials

One unopened Wal-Mart HomeTrends Kids "Duck Pond" PVC 70"x 71" shower curtain was purchased on December 18, 2007 from Wal-Mart in San Leandro, CA and shipped to Air Quality Sciences for analysis. A representative sample of about 6.5 x 6.5 inches was cut from the shower curtain to achieve a target product testing load of 0.6 m^2/m^3 for the test chamber. This loading factor is comparable to a 70" x 71" curtain in a 6 x 6 x 8 foot bathroom. The curtain was cut with contaminant-free tools and the study sample was placed in a small stainless steel environmental chamber, 23.62" x 18.90" x 11.81" in size, supplied with purified air at 23°C, 50% relative humidity, and 0.5 air changes per hour. These chamber conditions are typical of an indoor residential environment. The study sample was elevated off the floor of the chamber so that two sides of the curtain were exposed to the air in the chamber (see photo, page 22). Supply air to the chamber was filtered to

Mom and baby hanging the same brand PVC shower curtain as the one tested by Air Quality Sciences. This curtain released a total of 108 different volatile organic compounds into the air over the course of 28 days.

Photo Courtesy of © Stacey Vaeth

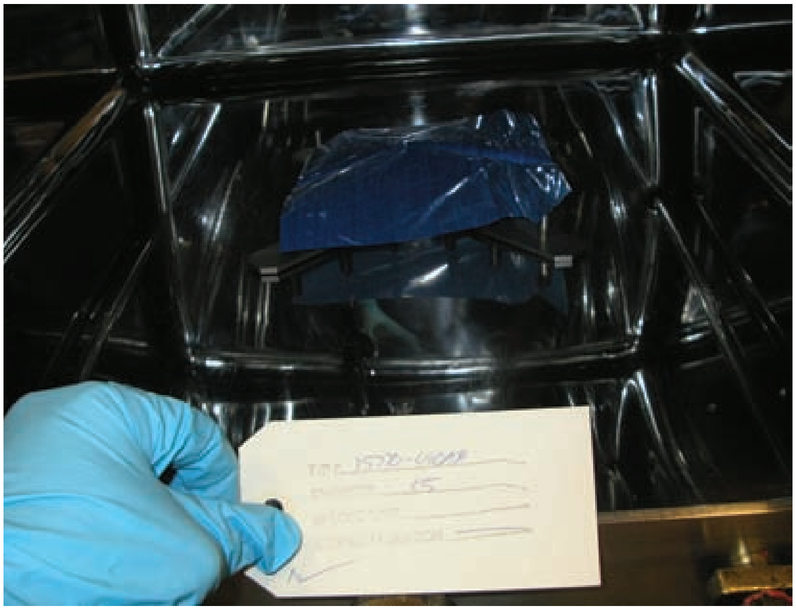

Photo Courtesy of © Air Quality Sciences

Sample of PVC shower curtain in the testing chamber at Air Quality Sciences laboratory.

remove VOCs, particles and other contaminants. Background air samples were taken, and chemical measurements were done for all chemicals being tested prior to the introduction of the shower curtain to the chamber to ensure it was contaminant-free. Empty chamber background measurements collected for VOCs were below the quantifiable level of 2 µg/m^3. The background measurements collected for phthalates were below the quantifiable level of 7.4 µg/m^3. No duplicate air measurements were performed. The chamber was equipped with a continuous data acquisition system for verification of operating conditions, such as temperature, relative humidity, and airflow.

The chamber air samples were collected at the following times: 0, 6, 24, 48, 72, 96 and 168 hours; and 14, 21, and 28 days. The sample remained in the same chamber for the entire study period. In between sampling periods, purified air was supplied at 23ºC, 50% relative humidity, and 0.5 air changes per hour. The chamber conditions are described in more detail in Appendix C.

Volatile Organic Compound (VOC) emissions were analyzed using gas chromatography with mass spectrometric detection (GC/MS). Chamber air was collected onto Tenax TA sorbent tubes at 0.2 liters per minute (L/m) for 90 minutes. The tube was then thermally desorbed into the GC/MS. The sorbent collection, separation, and detection methodology was adapted from techniques reported by USEPA and other researchers. The technique used follows USEPA Method IP-1B and ASTM D 6196 and is generally applicable to C_6 to C_{16} organic chemicals with boiling points ranging from 35ºC to 250ºC. Measurements were reported to a quantifiable level of 2 micrograms per cubic meter (µg/m^3). These methods are described in more detail in Appendix C.

Total Volatile Organic Compounds (TVOCs) were analyzed by adding all individual VOC responses obtained by mass spectrometer and calibrating the total mass relative to toluene as a standard. Individual VOCs from C_6 to C_{16} were also quantified relative to toluene and identified using AQS' specialized indoor air mass spectral database. Other compounds were identified with less certainty using a general mass spectral library available from the National Institute of Standards and Technology (NIST). This library contains mass spectral characteristics of more than 75,000 compounds as made available from NIST, the USEPA and the National Institutes of Health (NIH).

Phthalate concentrations were analyzed using OSHA Method 104. Air samples were collected

"It smelled horrible! When I first brought it home and put it up, everyone thought I had sprayed ROACH SPRAY throughout the house. Man I couldn't get rid of that smell for days. I used Fabreeze and put detergent on it and it didn't work. It was so strong, I couldn't stand to go in that bathroom. Took my breath away. Anyway, it eventually subsided within a week. BUT man what are they trying to do… Kill me!"

on an OVS Tenax sorbent tube at 1 L/m for a 4 hour period. The collected phthalates were chemically desorbed and analyzed by gas chromatography with a flame ionization detector (GC/FID). Sampled sorbent tubes were labeled and appropriate chain of custody forms completed for the transfer of the samples to STAT Analysis Corporation (Chicago, IL). The tubes were stored in a freezer at -15ºC to -20ºC until shipping. The tubes were shipped cold overnight to STAT Analysis in two batches, after 168 hours and at the conclusion of the chamber study. The reporting limit for this analysis was 7.4 µg/m^3. The lab analyzed a total of 16 phthalates. The complete list and quality control procedures are described in Appendix C.

Test Results

High Levels of Volatile Organic Compounds (VOCs) Released from Vinyl Shower Curtain

A portion of a vinyl shower curtain was placed in an environmental chamber and allowed to evaporate for 28 days. Volatile organic compounds and phthalates were analyzed at different time points. See Appendix A for the complete VOC test results. This testing showed the following results.

- Volatile organic compounds (VOCs) were released from a PVC shower curtain for 28 days after the curtain was opened. Several VOCs were found at high concentrations during the initial 2-3 days of testing.
- A total of 108 different volatile organic compounds were released from the shower curtain through the course of these 28 days. A complete list of the chemicals found and their concentrations in the chamber is shown in Appendix A. Highlights include:
  - 40 different VOCs were detected in the chamber after 7 days.
  - 16 different VOCs were detected after 14 days;
  - 11 different VOCs were detected after 21 days; and
  - 4 different VOCs were detected after 28 days;
- Toluene, cyclohexanone, methyl isobutyl ketone (MIBK), phenol, ethylbenzene, and xylenes were detected in the greatest concentrations throughout the 28-day period (see Table 8). The USEPA also found all of these substances except cyclohexanone in their study of chemicals off-gassing from PVC shower curtains (Chang 2002).

Testing for Total VOCs: High Levels Found

The concentration of the Total Volatile Organic Compounds (TVOCs) was measured at each time point in the study. TVOC measures the sum total concentration of all the volatile organic compounds present in a sample from C_6 to C_{16}. Total VOC concentration decreased over time, with some VOCs still detectable on the 28th day. The concentration of Total VOCs measured in the chamber at the 24 hour sampling point was over 4,000 µg/m^3. The results are shown in Table 9 (page 24).

TABLE 8 **Highest Concentrations of Volatile Organic Compounds (µg/m^3) Released from PVC Shower Curtain**

	Time Following Placement of Shower Curtain in Chamber								
Compound Identified	**6 hours**	**1 day**	**2 days**	**3 days**	**4 days**	**7 days**	**14 days**	**21 days**	**28 days**
Toluene	2,090	1,220	538	136	37.9	2.3	ND	ND	ND
Cyclohexanone	2,030	1,060	813	522	391	156	12.5	3.0	ND
Methyl isobutyl ketone (MIBK)	907	577	325	131	64.7	7.4	ND	ND	ND
Phenol	394	266	208	138	80.9	20.6	ND	ND	ND
Ethylbenzene	371	87.3	24.1	5.3	ND	ND	ND	ND	ND
Xylene (para and/or meta)	315	73.3	24.0	6.9	2.7	ND	ND	ND	ND

Notes: ND = Not Detected, below the Limit of Detection. Individual volatile organic compounds are calibrated relative to toluene; see Appendix A for the complete list of 108 chemicals found in study.

Photo : © Jupiter Images

TABLE 9 **Concentrations of Total Volatile Organic Compounds (TVOCs) (µg/m^3) Released from PVC Shower Curtain Over Time**

Timeframe	TVOC Concentration (µg/m^3)
6 hours	8,430
1 day	4,460
2 days	2,840
3 days	1,690
4 days	1,010
7 days	515
14 days	107
21 days	56.9
28 days	31.2

Testing for Phthalates

Due to elevated limits of detection for the phthalates in the chamber study, the analysis did not produce quantifiable results. All samples taken were below the limit of detection. The analytical method used by STAT Analysis Corporation had an average detection limit of 7.4 µg/m^3, well above the typical levels found in other off-gassing studies. The lab was not able to achieve the lower detection limits necessary to identify phthalates off-gassing to the air of the small chamber for this study. CHEJ is considering an additional investigation with a laboratory that could achieve the lower detection limits needed, since initial results indicated the presence of phthalates in shower curtains.

A number of studies have documented phthalates off-gassing from vinyl products. In one study, di(2-ethylhexyl) phthalate (DEHP) was detected at a maximum concentration of 1 µg/m^3 (Afshari 2004). The same result was observed in another study in new cars at room temperature (TUV Nord 1996). Studies of PVC wall coverings showed DEHP was present at slightly less than 1 µg/m^3, though the maximum phthalate concentration for di-n-nonyl phthalate (DNP) reached 5.10 µg/m^3 (Uhde 2001). A fourth study found the 90th percentile concentrations in indoor air to be 1.56 µg/m^3 for diethyl phthalate (DEP) and 0.426 µg/m^3 for di-n-butyl phthalate (Rudel 2003).

CHAPTER 5

Implications of Test Results

The study found that the familiar "new shower curtain smell" contains dangerous chemicals such as VOCs, and these chemicals contribute to indoor air pollution in our homes.

PVC Shower Curtains Contain High Levels of Toxic Chemicals

The study found PVC shower curtains contain high levels of avoidable toxic chemicals including volatile organic compounds (VOCs) and phthalates. In general, VOCs can cause eye, nose, and throat irritation; headaches, loss of coordination, nausea; and damage to the liver, kidney, and central nervous system. Some VOCs can cause cancer in animals; some are suspected or known to cause cancer in humans. Key signs or symptoms associated with VOC exposure include eye irritation, nose and throat discomfort, difficulty breathing, allergic skin reaction, headache, nausea, vomiting, fatigue, dizziness, and nose bleeding (USEPA 2007a).

Phthalates have been linked to reproductive problems including shorter pregnancy duration (Latini 2003), premature breast development in females (Colon 2000) and sperm damage (Duty 2003) and impaired reproductive development in males (Swan 2005). Since phthalates are not chemically bound to the shower curtain, they can easily migrate from within the curtain to its surface. They may slowly evaporate into the surrounding air and eventually cling to household dust (Wormuth 2006).

The testing found PVC shower contains contain low levels of organotins and certain metals. Since the organotins are not chemically bound to the shower curtain, they can migrate from within the curtain to its surface (Goettlich 2001). To what extent they may volatilize is uncertain and needs to be further explored. Some organotins affect the central nervous system, skin, liver, immune system and reproductive system (WHO 1980, Pless 2002). Diorganotins in particular are potent developmental toxins and teratogens (Ema 1995, Pless 2002, Noda 1993).

PVC Shower Curtains Release High Levels of VOCs

The study found that VOCs are not only present in PVC shower curtains, but are released into the air at high concentrations in some cases. Testing detected 108 VOCs are released from the vinyl shower curtain, and a number of chemicals persisted for almost a full month. The chemicals found at the highest concentrations were toluene, ethylbenzene, phenol, methyl

Photo: © iStockphoto

TABLE 10 **Adverse Health Effects Associated with VOCs Found to Off-Gas from PVC Curtain**

Volatile Organic Chemical	Adverse Health Effects
Cyclohexanone	Cataracts[2]; respiratory irritant[2]; nervous system depression[1]; liver[1] and kidney damage[2]
Decane	Irritant (respiratory)[2]; nervous system depression[1]; shortness of breath[2]; narcotic effects[2]
Dipropylene glycol methyl ether	Irritant (skin[1,2], eye[1,2], nose[2], throat[2]); liver damage[2]; narcotic effects[2]
Ethanol, 2-(2-butoxyethoxy)*	Eye irritant[1]; nervous system depression[1]; kidney damage[1]
Ethylbenzene	Irritant (skin, respiratory, eye)[1,2]; possible carcinogen[2]; narcotic effects[2]; nervous system disorders[1]; liver damage[2]; hematological disorders[1]; may damage developing fetus[2]
Methyl Isobutyl Ketone (MIBK)	Irritant (skin, respiratory, eye)[1,2]; nervous system depression[1,2]; liver and kidney damage[2]
Phenol	Mutagen[2]; heart arrhythmia[2]; pulmonary edema[2]; depression (nervous system[1], cardiovascular system[1]); liver[2] and kidney damage[1,2]
Toluene	Irritant (skin, nose, throat)[2]; developmental and reproductive toxicant[1,2]; narcotic effects[2]; nervous system disorders[1]; liver and kidney effects[1]
Undecane	Irritant (skin, respiratory, eye)[1]; shortness of breath[2]
Xylene	Irritant (skin[2], eye[2], respiratory[1,2]); narcotic effects[2]; liver and kidney damage[2]; brain effects[2]; nervous system depression[1]; may damage developing fetus[2]

Note: *HSDB includes this chemical under the alternate name, diethylene glycol mono-n-butyl ether.
Sources: 1. Hazardous Substances Data Bank 2008. 2. New Jersey Right to Know Hazardous Substances Fact Sheets 2008.

isobutyl ketone (MIBK), cyclohexanone, and xylenes. These results are consistent with testing of a vinyl shower curtain conducted by the USEPA which found toluene, ethylbenzene, phenol and, MIBK (Chang 2002). A number of these chemicals can cause central nervous system, liver, and respiratory damage (see Table 10) and some of the chemicals can cause other problems such as reproductive and developmental health problems.

Seven of the chemicals detected are classified as hazardous air pollutants by the EPA under the Clean Air Act (USEPA 2007b). These chemicals are toluene, ethylbenzene, phenol, MIBK, xylene, acetophenone, and cumene. Two of the chemicals released by the curtain, toluene and ethylbenzene, are on California's Proposition 65 list. This state law prohibits companies doing business in California from exposing individuals (above a certain threshold) to chemicals known to cause cancer or reproductive toxicity without first giving clear and reasonable warning. The law also prohibits the discharge of such chemicals into drinking water (COEHHA 2007).

One limitation of this study is that the testing did not replicate temperature and humidity conditions typically found in a bathroom during a shower. Heat and temperature may *increase* the air concentrations of volatile pollutants (CARB 1999, USEPA 2007c). Conditions typical to bathrooms with showers would likely increase the concentrations of leached VOCs found in the air of a bathroom. It is likely, therefore, that the concentrations measured in this study are under-estimates of the typical chemical concentrations encountered by people from PVC shower curtains in the home.

PVC Shower Curtains Contribute Significantly to Indoor Air Pollution

The study shows that PVC shower curtains contribute significantly to indoor air pollution, releasing potentially harmful levels of VOCs into indoor air. PVC shower curtains also contain toxic phthalates, organotins, and metals. The phthalates and possibly the organotins may also be released into the air over time.

The USEPA has ranked indoor air pollution 4th in cancer risk among the top 13 environmental problems analyzed (CARB 2006). Indoor air pollution has also been ranked a major risk to human health by the World Health Organization, American Lung Association and numerous other public health and environmental agencies and organizations (Greenguard 2008). Indoor concentrations of VOCs have been found to be greater than outdoor concentrations. A study by the USEPA, covering six communities across the United States, found indoor levels of VOCs up to ten times higher than those outdoors—even in locations with significant outdoor air pollution sources (USEPA 1994).

Some studies have found that mixtures of low levels of VOCs can cause sensory irritation responses (Greenguard 2008a). Many studies have found that Total VOC levels are typically higher indoors than they are outdoors (Greenguard 2008a). One study of 174 homes in Britain found Total VOC concentrations were usually 10 times higher inside than outside (Greenguard 2008a). Since people spend a large portion of time in their home, they may be exposed to harmful levels of chemicals released from vinyl shower curtains, as well as other vinyl consumer and building products (Greenguard 2008).

Most buildings have total VOC levels ranging from 100 to 500 $\mu g/m^3$ with residential levels averaging 1,000 $\mu g/m^3$. Total VOC levels above 500 $\mu g/m^3$ may result in irritation to some building occupants (Greenguard 2008a). This study found just one new vinyl shower curtain will release Total VOCs that *exceed* the typical residential level of 1,000 ug/m^3 for four days.

A number of recent green and healthy building programs such as the U.S. Green Building Council's (USGBC) LEED program and the State of Washington Indoor Air Quality (IAQ) Program have established a level of 500 $\mu g/m^3$ of Total VOCs as an acceptable building clearance level prior to occupancy (Greenguard 2006). This study shows that one new PVC shower curtain can release Total VOCs that are significantly higher than this recommended level. The total VOC level in this study was over 16 times higher than the State of Washington and USGBC recommended standard after 6 hours (see Table 9).

Testing of PVC Shower Curtain Consistent with USEPA Results

The results of this study are consistent with previous testing conducted by the U.S. and Danish Environmental Protection Agencies on PVC shower curtains. In a 1991 study, scientists at the US EPA's Atmospheric Research and Exposure Assessment Laboratory studied emissions of a broad range of volatile organic chemicals found in various commonplace products and environments (Wallace 1991). A new PVC shower curtain was included in these studies, and the main chemicals detected were ethylene dichloride and decane. Decane was also detected in our study, though ethylene dichloride was not.

A second group at USEPA focused on emissions of four chemicals — toluene, phenol, ethylbenzene and methyl isobutyl ketone (MIBK) from a PVC shower curtain. These substances were chosen because they are classified as hazardous air pollutants by the federal Clean Air Act. The EPA found these pollutants were released from a vinyl shower curtain in a contained space similar to a common bathroom. Elevated indoor concentrations of each of these substances (toluene, phenol, ethylbenzene, and MIBK) were found to persist beyond one month (Chang 2002). The maximum air concentrations of toluene and MIBK far exceeded Short-Term Exposure Limits set for workplace exposures (Chang 2002). All four of these same chemicals were detected in our study as well. In fact, the concentrations of these four chemicals were among the five highest levels found in this study (see Table 8).

A study by the Danish EPA found vinyl shower curtains contain organotins and high levels of the phthalate DEHP (Danish EPA 2001). Our study also found high levels of DEHP in three of the five PVC shower curtains tested (see Table 5) and organotins in three of the five curtains tested (see Table 6).

VOCs Released by other PVC Products

VOCs have also been found to off-gas from other PVC consumer products such as vinyl flooring. A study by the California Air Resources Board analyzed forty target compounds off-gassing from PVC flooring. Phenol, tetrahydro-furan, cyclohexanone, toluene and n-tridecane were all found (CARB 1999). Three of these same compounds (phenol, cyclohexanone, and toluene) were also found to off-gas from a PVC shower curtain in our study. Another study on volatile chemicals present in new houses included an analysis of volatile organic compounds emitted from vinyl flooring. Emissions of most chemicals were relatively constant over a period of nine months, indicating a persistent risk of toxic exposure (Hodgson 2000).

PVC Products in the Home May Lead to Asthma

In recent years, consumers have complained of headaches, nausea and other health impacts that may be associated with exposure to chemicals found in PVC shower curtains (see quotes interspersed throughout the report). Volatile organic compounds off-gassing from PVC products such as vinyl shower curtains may contribute to adverse health problems for consumers as has been documented in a recent study investigating asthma and PVC flooring and wall coverings. In this study, workers in an office building were diagnosed with adult-onset asthma at a rate approximately 9 times higher than expected. High levels of VOCs, such as 2-ethyl-l-hexanol, l-butanol, which are degradation by-products of vinyl, were detected. The researchers concluded the most probable cause of this indoor air problem was the degradation of the PVC flooring (Tuomainen 2004).

A number of studies have also suggested a correlation between phthalates, PVC and asthma. Most recently, a study published in 2008 found an association between concentrations of DEHP in indoor dust and wheezing among preschool children in Bulgaria (Kolarik 2008). Another study of 10,851 children found the presence of both floor moisture and PVC significantly increased the risk of asthma (Bornehag 2002). PVC wall coverings have also recently been linked to asthma. A recent study from Finland found that adults working in rooms with plastic wall coverings were more than twice as likely to develop asthma. These researchers pointed to other recent epidemiologic studies in children conducted in Norway, Finland, Sweden, and Russia that also found links between PVC, phthalates, and respiratory problems (Jaakkola 2006).

No Federal Standards Exist to Protect the Air in Our Homes from Toxic Chemicals Released by Consumer Products

No federal agency has the legal authority to regulate the consumer products that release toxic chemicals into the air inside our homes. Neither the EPA, which regulates the ambient air (USEPA 2008), nor the Consumer Product Safety Commission (CPSC), which regulates chemicals in consumer products, can do this. Therefore, no standards for toxic chemicals in indoor residential air have been set, despite the fact that studies show VOCs are typically higher in indoor air than outdoor air and are a major health concern. It's clear our chemical regulatory system is broken and needs to be fixed.

> **"While we do regulate VOCs in outdoor air, from an indoor air perspective, EPA has no authority to regulate household products (or any other aspect of indoor air quality)…. Even if we had authority to regulate indoor air quality, it would be difficult to regulate household products because we have no authority to collect information on the chemical content of products in the marketplace (nor does any Federal Agency)."**
>
> – U.S. ENVIRONMENTAL PROTECTION AGENCY (USEPA 2008).

CHAPTER 6

Company Policies on PVC Shower Curtains

As part of our investigation into the dangers of PVC shower curtains, CHEJ contacted leading retailers around the world to determine whether or not companies have developed plans to phase out PVC shower curtains. We found a number of leading retailers have adopted policies to reduce or phase out PVC shower curtains in light of the growing body of evidence demonstrating that PVC contains and releases dangerous chemicals from production to disposal. These company policies are summarized below.

IKEA Sets Example: First to Phase Out PVC Shower Curtains

IKEA set an international standard and became the first major retailer to phase out PVC shower curtains over 11 years ago, switching to ethylene vinyl acetate (EVA) as a plastic alternative (Fritiof 2006).

Target Expects 88% of its Shower Curtains to Be PVC-free

Target, Inc., the country's fifth largest retailer, has committed to replacing many PVC shower curtains with EVA, a safer PVC-free plastic. Target expects 88% of its shower curtains to be PVC free by the spring of 2008 (Hanson 2007, Kahn 2007, Target 2007).

Sears and Kmart Develop PVC-free Policy Focusing on Shower Curtains

Sears Holdings, the publicly traded parent of Kmart and Sears, Roebuck and Co., is the nation's sixth-largest retailer. In December 2007, the company announced a major new PVC-free policy to reduce and phase out PVC in its packaging and merchandise. One of the first merchandise areas the company is focusing on is PVC shower curtains. Sears Holdings found that most of their vendors were already aware

Photo: © iStockphoto

of the industry trends to phase out PVC and are moving towards other alternatives such as EVA and polyethylene vinyl acetate (PEVA) blends (Zonooz 2008).

Bed Bath & Beyond Steps Up Alternatives

Bed Bath & Beyond, Inc., a chain retailer of home and domestic products that operates in 48 states, has increased their presence of PVC-free shower curtains, shifting towards EVA and fabrics. The company expects this trend will continue; however, the company has not set a 100% PVC-free shower curtain goal or time-frame. The company's work with vendors also secured PVC-free shower curtain packaging (Denenberg 2008, BBB 2007).

"I have a 2500 sq. ft. home and this shower curtain in my daughter's upstairs bath stunk up the whole house. I believe there are dangerous chemicals in it, so I returned it! It should be recalled!!"

JC Penney Developing PVC-free Policy

JC Penney, an apparel and home furnishing retailer with over 1,000 stores nationwide, has committed to "working towards replacing PVC," which will include a PVC-free policy and its first corporate social responsibility report, to be published in April 2008. JC Penney will work toward finding alternatives to vinyl shower curtains, however, they have not set a 100% PVC-free shower curtain goal or timeframe (Thomas 2008).

Where Does Wal-Mart Stand on PVC Shower Curtains?

CHEJ mailed and faxed letters to Wal-Mart Stores, Inc. inquiring whether or not the company has a policy on PVC shower curtains (Weigand 2007). Unfortunately, we have received no response from the company to date. We can only assume that Wal-Mart does not have a policy or timeframe to phase out PVC shower curtains. This is disappointing since the company has made efforts to reduce or eliminate PVC private label packaging, lunch boxes, and baby bibs; has begun exploring PVC-free building materials; and supports eliminating PVC in children's toys (Schade 2007).

Macy's Offers PVC-Free Shower Curtains

Macy's, Inc., operating in 45 states, has a selection of shower curtains made from alternative plastics to choose from, such as EVA, as well as textile fabrics. They plan to continue to work toward nontoxic products (Sluzewski 2008), however Macy's has not set a 100% PVC-free shower curtain goal or timeframe.

Marks & Spencer Eliminates PVC Shower Curtains

Marks & Spencer Group plc, a leading retailer of apparel, home furnishings, and food in the United Kingdom and worldwide, has been aggressively eliminating all PVC shower curtains. As of Spring 2008, all shower curtains are PVC-free and are made out of other materials such as PEVA (Carroll 2008, Marks & Spencer 2007).

CHAPTER 7

Recommendations

Based on the results of this study, industry and government need to implement an immediate phase-out of PVC in all shower curtains. We recommend the following actions to prevent harm and halt toxic air pollution in people's homes.

Corporate and Government Policy Recommendations

Manufacturers and retailers should implement the following actions.

- Phase out PVC shower curtains and switch to safer products such as organic cotton shower curtains.
- Label the material content of shower curtains so that consumers can easily identify safer products. Shower curtains without PVC should be labeled "PVC-free." By requiring all PVC products to be labeled, consumers can readily identify where PVC is used in the home.
- Label PVC shower curtains with warnings of the chemicals present in the new shower curtain smell.

Governments at all levels should implement the following actions.

- Act quickly to adopt policies to protect consumers and ban the use of PVC in shower curtains.
- Adopt PVC-free procurement policies to help build markets for safer products.
- Require warning labels on PVC shower curtains. Warnings should alert consumers to the fact that over 100 chemicals can be released during use in the home. Labeling would also encourage product manufacturers to switch to safer products to avoid labeling requirements.
- Require that PVC shower curtains and other PVC products be collected and diverted from burn barrels and incinerators to reduce the formation of dioxins and furans; PVC should be treated as a hazardous material. As an interim measure, PVC could be disposed of in "secure" triple-lined hazardous waste landfills.
- Conduct a public campaign to educate consumers about the risks posed by PVC products such as shower curtains in the home.

Photo : © Jupiter Images

The Consumer Product Safety Commission should recall PVC shower curtains on the market and require manufacturers to switch to safer products.

"I bought this for my 4 year old daughter. I brought it home and it had a horrible plastic smell, so I unfolded it and let it sit outside for 2 DAYS!! I put it up in the bathroom and everytime (sic) I walked past, my eyes began to tear (not to mention my nose protested against the smell). Even my 4 year old didn't want it! We took it back! Go for the fabric one...."

Federal policymakers should reform America's outdated chemical policies that are failing to protect families from toxic chemicals already on the market that are released in our homes. The federal law regulating industrial chemicals, the Toxic Substances Control Act (TSCA), is 30 years old, outdated, and simply does not work to protect people and the environment. PVC in shower curtains is one of many examples of the need to reform federal law to protect consumers. **TSCA must be amended to:**

- Require complete and credible health and safety data on chemicals and make this data publicly available;
- Require companies that legally manufacture or import chemicals into the U.S. to provide minimum toxicity data;
- Require product manufacturers to test for and publicly disclose the chemical contents of their products;
- Prohibit the use of dangerous chemicals such as carcinogens, mutagens, reproductive toxicants, and persistent bioaccumulative toxic (PBT) chemicals in products, especially those found in the home and targeted at infants and children, or that accumulate in our bodies;
- Create health-based standards for VOCs and other chemicals in the air in consumers' homes;
- Provide consumers with information so they can make informed purchases by requiring the disclosure of chemical information and warning labels; and
- Provide information, funding, research, and technical resources in "green chemistry" to businesses so they can make products such as shower curtains safe for consumers, with incentives to invest in green economic development to spur innovation in safer products.

Recommendations for Consumers

- Avoid shower curtains made with PVC, as well as other PVC products, especially those that are flexible. These products are not always labeled, although some may be labeled as "vinyl" or "PVC." Do not buy shower curtains that are not labeled.
- Purchase PVC-free shower curtains made out of safer materials including organic cotton.

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APPENDIX A

Concentrations of Volatile Organic Compounds Released from PVC Shower Curtain

Concentrations of Volatile Organic Compounds (µg/m³) Released from PVC Shower Curtain

Compound Identified	Timeframe								
	6 hours	1 day	2 days	3 days	4 days	7 days	14 days	21 days	28 days
Toluene (Methylbenzene)	2,090	1,220	538	136	37.9	2.3	ND	ND	ND
Cyclohexanone	2,030	1,060	813	522	391	156	12.5	3.0	ND
2-Pentanone, 4-methyl (Methyl isobutyl ketone, MIBK)	907	577	325	131	64.7	7.4	ND	ND	ND
Phenol	394	266	208	138	80.9	20.6	ND	ND	ND
Benzene, ethyl	371	87.3	24.1	5.3	ND	ND	ND	ND	ND
Xylene (para and/or meta)	315	73.3	24.0	6.9	2.7	ND	ND	ND	ND
Ethanol, 2-(2-butoxyethoxy)	280	240	195	189	179	93.8	3.2	2.3	ND
Decane	207	54.4	23.7	9.4	ND	ND	ND	ND	ND
Undecane	173	51.6	21.9	9.3	3.9	ND	ND	ND	ND
2-Propanol, 1-(2-methoxypropoxy)-*	127	54.0	39.2	20.0	12.0	5.4	ND	ND	ND
Nonane, 2,3-dimethyl*	98.3	32.3	22.9	13.1	8.2	ND	ND	ND	ND
Cyclohexane, butyl	92.7	32.4	23.2	12.3	4.7	ND	ND	ND	ND
Decane, 2-methyl	69.7	21.4	13.6	6.8	3.7	ND	ND	ND	ND
Decane, 3-methyl	63.9	20.7	14.4	8.0	4.5	2.1	ND	ND	ND
Decane, 5-methyl*	62.4	20.2	13.8	7.2	4.4	2.4	ND	ND	ND
Octane, 2,5,6-trimethyl*	56.4	21.9	16.3	10.1	2.2	ND	ND	ND	ND
Nonane, 2,6-dimethyl*	51.4	23.1	18.0	6.7	9.4	ND	ND	ND	ND
Dipropylene glycol monomethyl ether	49.0	17.6	13.7	7.3	4.4	ND	ND	ND	ND
Decane, 3,6-dimethyl*	48.4	17.0	10.9	6.5	2.6	ND	ND	ND	ND
Cyclohexane, 1-ethyl-2-propyl*	42.3	14.5	12.0	6.6	3.7	ND	ND	ND	ND
Decane, 4-methyl	40.6	12.5	7.4	3.6	ND	ND	ND	ND	ND
Hexanoic acid, 2-ethyl-, methyl ester*	40.2	46.8	47.8	54.4	15.5	16.7	22.7	12.8	10.7
Nonane, 2,5-dimethyl*	38.9	15.0	9.9	5.5	3.4	ND	ND	ND	ND
Nonane, 3,7-dimethyl*	37.4	11.9	7.9	8.1	6.5	4.1	ND	ND	ND
2-Butanone (Methyl ethyl ketone, MEK)	35.8	101	8.4	ND	ND	ND	ND	ND	ND
Cyclohexane, pentyl*	31.0	10.6	7.6	4.5	ND	ND	ND	ND	ND
Cyclopentane, hexyl-*	30.0	10.7	7.4	4.1	2.1	ND	ND	ND	ND
t-Decahydronaphthalene	26.7	8.3	7.4	3.6	2.8	ND	ND	ND	ND
1-Dodecene	24.3	11.4	9.2	6.6	ND	ND	ND	ND	ND
Nonane	23.9	4.7	ND	ND	ND	ND	ND	ND	ND

Compound Identified	Timeframe								
	6 hours	1 day	2 days	3 days	4 days	7 days	14 days	21 days	28 days
Acetophenone (Ethanone, 1-phenyl)	23.2	12.9	9.0	6.0	3.6	3.2	ND	ND	ND
Decane, 3,7-dimethyl-*	22.9	6.4	5.4	ND	ND	3.6	ND	ND	ND
Nonane, 2-methyl	22.7	6.0	3.6	ND	ND	ND	ND	ND	ND
Cyclohexane, 1-methyl-4-(1-methylbutyl)-*	21.7	7.3	6.0	3.8	ND	ND	ND	ND	ND
7-Tetradecene, (E)*	21.3	18.6	25.2	29.2	10.6	23.6	ND	ND	ND
Acetate, butyl	21.1	3.7	ND	ND	ND	ND	ND	ND	ND
2-Propanol, 1-(2-methoxy-1-methylethoxy)*	20.9	10.5	8.0	4.6	3.4	ND	ND	ND	ND
Nonane, 4-methyl	18.1	6.2	2.6	ND	ND	ND	ND	ND	ND
1-Ethyl-2,2,6-trimethylcyclohexane*	18.1	6.0	5.7	3.4	ND	ND	ND	ND	ND
Undecane, 3-methyl*	17.7	6.9	5.1	3.4	ND	ND	ND	ND	ND
Tridecane	17.5	18.4	ND	ND	ND	ND	ND	ND	ND
7-Tetradecene, (Z)*	17.5	12.4	26.5	11.6	ND	ND	ND	ND	ND
Benzene, 1-methylethyl (Cumene)	17.4	4.4	2.6	ND	ND	ND	ND	ND	ND
Neodecanoic acid*	17.3	23.2	23.8	30.9	25.8	27.1	16.7	13.1	9.8
2-Methyl-3-ethyl-2-heptene*	16.6	6.4	6.7	3.6	4.6	ND	ND	ND	ND
Benzothiazole	14.9	6.3	4.5	2.8	ND	2.0	ND	ND	ND
3-Penten-2-one, 4-methyl*	13.9	3.5	ND	ND	ND	ND	ND	ND	ND
Decane, 2,9-dimethyl*	13.7	4.8	3.7	ND	ND	ND	ND	ND	ND
2-Dodecene, (Z)-*	12.4	6.2	6.2	4.5	ND	ND	ND	ND	ND
Undecane, 2-methyl	11.9	3.9	3.2	2.9	ND	ND	ND	ND	ND
Decane, 3,8-dimethyl*	11.5	3.3	2.4	ND	ND	ND	ND	ND	ND
1(3H)-Isobenzofuranone*	11.2	7.5	7.1	6.6	ND	4.2	ND	ND	ND
Nonane, 5-methyl	11.2	2.7	2.6	ND	ND	ND	ND	ND	ND
Cyclohexane, 1-methyl-4-isopropyl, trans	11.0	5.6	4.9	2.0	ND	ND	ND	ND	ND
Cyclohexane, propyl	10.9	5.8	4.4	2.0	ND	ND	ND	ND	ND
5-Tetradecene, (E)*	10.7	5.8	6.4	2.9	ND	ND	ND	ND	ND
Octane, 2,6-dimethyl	9.7	3.8	2.4	ND	ND	ND	ND	ND	ND
7-Tetradecene*	9.5	6.8	5.9	6.3	ND	ND	ND	ND	ND
Cyclotetradecane	9.2	3.7	3.1	6.0	ND	ND	ND	ND	ND
Tetradecane	8.4	5.0	7.8	7.5	ND	4.0	3.7	ND	ND
Octane	8.2	3.3	ND	ND	ND	ND	ND	ND	ND
6-Tetradecene, (E)-*	7.9	5.3	6.8	5.5	ND	ND	ND	ND	ND
Cyclohexane, 1-ethyl-2,3-dimethyl*	7.7	4.7	4.0	2.3	2.4	ND	ND	ND	ND
Undecane, 4-methyl*	7.6	2.4	ND	ND	ND	ND	ND	ND	ND

Compound Identified	Timeframe								
	6 hours	1 day	2 days	3 days	4 days	7 days	14 days	21 days	28 days
Heptane, 3-ethyl-2-methyl	7.3	4.5	3.6	2.1	ND	ND	ND	ND	ND
Octane, 2,5-dimethyl*	6.5	ND	ND	ND	ND	ND	ND	ND	ND
Pentadecane	6.4	6.7	7.4	9.3	3.7	4.4	ND	ND	ND
1-Dodecanol	6.1	2.6	3.4	3.8	ND	2.5	ND	ND	ND
Dodecane, 2,6,11-trimethyl*	5.9	2.6	4.6	2.6	ND	ND	ND	ND	ND
1-Tridecene	5.5	ND	ND	ND	ND	ND	ND	ND	ND
Octanoic acid, 2-ethylhexyl ester*	5.4	4.0	6.5	6.8	3.3	4.4	ND	ND	ND
3-Hexadecene, (Z)-*	5.4	3.7	ND	2.1	ND	ND	ND	ND	ND
Tetradecane, 2-methyl*	5.0	3.1	3.5	3.1	ND	ND	ND	ND	ND
Tetradecane, 3-methyl*	4.5	3.5	3.3	4.4	ND	2.0	ND	ND	ND
Pentadecane, 3-methyl*	4.3	4.5	9.1	6.4	2.2	3.2	ND	ND	ND
Octane, 2,7-dimethyl	4.1	ND	ND	ND	ND	ND	ND	ND	ND
Hexadecane (Cetane)	4.0	6.0	7.3	6.8	6.6	6.1	2.5	2.2	ND
1-Hexadecene*	3.9	ND	ND	4.2	ND	5.4	ND	ND	ND
3-Nonene, (E)*	3.0	2.1	ND	ND	ND	ND	ND	ND	ND
Octane, 4-methyl*	2.2	ND	ND	ND	ND	ND	ND	ND	ND
Pentadecane, 6-methyl*	2.1	2.3	2.5	3.4	2.0	3.1	ND	ND	ND
Hexadecane, 7-methyl-*	2.1	2.1	3.3	9.1	9.4	11.0	3.1	2.3	ND
5-Tetradecene, (Z)-*	ND	5.9	3.5	3.4	ND	ND	ND	ND	ND
3-Heptene, 3,5-dimethyl*	ND	5.4	4.8	3.3	ND	ND	ND	ND	ND
Hexadecane, 4-methyl-*	ND	4.4	5.9	8.7	9.1	6.1	3.1	2.3	ND
Pentadecane, 2-methyl*	ND	3.8	3.2	2.7	2.7	2.9	ND	ND	ND
Hexadecane, 2-methyl-*	ND	3.4	2.4	6.0	5.6	6.0	2.4	ND	ND
Tetradecane, 2,6,10-trimethyl-*	ND	2.9	3.9	7.3	5.1	6.8	4.3	2.6	ND
Dodecane, 2-methyl-6-propyl*	ND	2.6	3.4	ND	ND	ND	ND	ND	ND
Heptadecane	ND	2.1	2.5	5.2	4.1	5.6	3.7	2.8	ND
Hexadecane, 3-methyl*	ND	2.0	4.8	6.0	5.4	4.6	ND	ND	ND
Butanoic acid, 2-ethyl-2,3,3-trimethyl-*	ND	ND	54.0	59.0	28.3	31.9	10.3	8.2	6.5
Benzenemethanol, α,α-dimethyl-	ND	ND	5.2	3.8	2.5	ND	ND	ND	ND
1-Heptadecene*	ND	ND	3.8	5.3	ND	ND	3.0	ND	ND
1-Ethyl-4-methylcyclohexane*	ND	ND	2.4	ND	ND	ND	ND	ND	ND
Cyclohexane, 1-(cyclohexylmethyl)-2-ethyl-, trans-*	ND	ND	2.3	ND	ND	ND	ND	ND	ND
2-Undecene, 6-methyl-, (Z)*	ND	ND	ND	ND	2.2	2.8	ND	ND	ND
Cyclohexadecane*	ND	ND	ND	9.4	8.3	13.2	2.0	ND	ND
Cyclohexane, 1-methyl-2-propyl*	ND	ND	ND	ND	ND	3.8	ND	ND	ND
Dodecane, 2,6,10-trimethyl*	ND	ND	ND	2.1	ND	ND	ND	ND	ND

Compound Identified	Timeframe								
	6 hours	1 day	2 days	3 days	4 days	7 days	14 days	21 days	28 days
Eicosane	ND	ND	ND	ND	ND	ND	6.9	ND	ND
Heptadecane, 2-methyl*	ND	ND	ND	2.1	ND	ND	ND	ND	ND
Heptadecane, 7-methyl-*	ND	ND	ND	2.5	ND	2.4	ND	ND	ND
Heptadecane, 8-methyl-*	ND	ND	ND	2.8	ND	2.2	ND	ND	ND
Heptanoic acid, ethyl ester*	ND	ND	ND	ND	ND	ND	6.9	5.3	4.2
Tetradecane, 2,5-dimethyl*	ND	ND	ND	4.0	2.1	2.3	ND	ND	ND
Tetradecane, 6,9-dimethyl*	ND	ND	ND	4.4	2.4	3.8	ND	ND	ND
Tridecane, 4,8-dimethyl*	ND	ND	ND	2.0	ND	ND	ND	ND	ND

Notes: ND = Not Detected, below the Limit of Detection; **indicates NIST/EPA/NIH best library match only based on retention time and mass spectral characteristics with a probability of > 80%; individual volatile organic compounds are calibrated relative to toluene;* values below 2.0 µg/m^3 are for informational purposes only; chemicals were detected, but below the quantifiable level of 0.04 µg based on a standard 18 L air collection volume.

APPENDIX B

Southwest Research Institute Lab Report

To download the full Southwest Research Institute lab report, visit
http://www.chej.org/swrilabreport.pdf

APPENDIX C

Air Quality Sciences Lab Report

To download the full Air Quality Sciences lab report, visit
http://www.chej.org/aqslabreport.pdf

“At first we thought we had a gas leak it was so bad and then realized it was the new shower curtain...”

“When I first brought it home and put it up, everyone thought I had sprayed ROACH SPRAY throughout the house...”

“The smell of this one is strong enough to give you a headache...”

“I decided to take it down after EVERYONE in the house got nauseous.”

“Most of the day I left the bathroom vent on which helped a lot. But still, house guests could smell it from outside!”

“Everytime (sic) I walked past, my eyes began to tear...”

“I have a 2500 sq. ft. home and this shower curtain in my daughter’s upstairs bath stunk up the whole house.”

These quotes are excerpted from Target customer complaints, posted on Target.com, about odors from PVC shower curtains. In response, Target has offered more PVC-free shower curtains.

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