

Solvents & Industrial Chemicals

Introduction

A recent review found that more than 30 industrial chemicals were shown to have caused mammary gland tumors in at least one animal study.¹ While exposure is highest in certain workplaces, many of these solvents and other chemicals are commonly found in ambient air, drinking water, and consumer products. In this chapter we address some organic solvents: benzene, ethylene oxide, methylene chloride, styrene, tetrachloroethylene and other dry cleaning agents, and urethane; and industrial chemicals: acrylonitrile, isoprene, nitrobenzene, toluene diisocyanate mixtures, and nonylphenols. A discussion of consumer cleaning products and air fresheners is also included. Other related compounds mentioned here, but covered more completely elsewhere in this report, are: acetaldehyde, 1,3-butadiene, ethanol and nitromethane (see Section I, Chapter B.1, Air Pollutants); and perfluorooctanoic acids (see Section I, Chapter B.2, Persistent Organic Pollutants). Solvents are also addressed in Section I, Chapter C, Compounds in Personal Care Products.

Organic Solvents

Solvents are used to dissolve or extract other substances in industrial and consumer products such as paint thinners (e.g. toluene), nail polish removers, spot removers, detergents (e.g. terpenes, nonylphenols), and perfumes (e.g. ethanol). They are also employed in processes like dry cleaning (e.g. tetrachloroethylene) and chemical syntheses. Solvents are widely and routinely used and can enter the human body by ingestion, inhalation, and

skin absorption. Detection of organic solvents in breast milk confirms their availability to breast tissue.² Organic solvents or their metabolites are suspected of initiating or promoting breast carcinogenesis through genotoxic or related mechanisms.^{2,3} Table 1 provides an summary of the likelihood of exposure, mechanisms of concern and evidence of a link with breast cancer for selected organic solvents.

Evidence that common organic solvents are animal mammary carcinogens makes these compounds important targets for human studies.⁴ However, relatively few human breast cancer studies have assessed solvent exposure and controlled for potential confounding by other breast cancer risk factors.² One well-designed epidemiologic study found elevated risk of breast cancer among younger Danish women in occupations with greater overall exposure to solvents (Hansen,⁵ reviewed in Brody et al.²). Risk was about doubled for women with more than ten years in an exposed job and 15 years lag time (OR = 1.97; 95% CI = 1.39–2.79). A registry-based case control study of Canadian women found elevated incidence among both pre- and post-menopausal women employed in two industries with higher chemical exposure, with particularly high rates among those in dry cleaning which used tetrachloroethylene.(Band,⁶ reviewed in Brody et al.²).

However, findings from other studies examining breast cancer risk associated with industries and/or occupations with exposure to solvents have not been consistent. Ray et al. did not find a greater risk in exposed versus unexposed textile workers,⁷ while Peplonska et al. observed higher breast

cancer rates among Polish textile machine operators and tenders.⁸ The latter also found an association among those who worked in electronics manufacturing or as printing machine operators, but not among janitors or among health care workers likely to be exposed to ethylene

oxide. Occupational studies are often limited in their ability to evaluate the association between exposure and disease outcomes, especially longer-latency cancers. These limitations are outlined in the "Conclusions and Future Directions" subsection below.

Table 1. Selected Organic Solvents Linked to Breast Cancer

Compound(s)	Potential for Exposure	Mechanism(s) of Concern	Human/Animal Evidence
Benzene	More likely (HPV*, air, water, consumer products)	Mutagen (conflicting evidence) Mammary carcinogen	Measured in human milk; increased incidence of mammary gland tumors in rats and/or mice
Ethylene oxide	Undefined (HPV*, air, water, occupational)	Mutagen Mammary tumorigen and carcinogen	Increased incidence of mammary gland tumors in mice (lower dose); some human evidence (occupational, drinking water)
Methyl chloride	HPV*, consumer products, air, water, occupational	Mammary carcinogen, fibroadenomas possible genotoxicity	Measured in human milk; increased incidence of mammary gland tumors in rats and/or mice
Styrene	More likely (HPV*, occupational, air, food)	Mutagen	Limited animal evidence; one occupational study of mortality
Tetrachloroethylene (Perc)	Undefined (occupational)	Possible genotoxicity	Measured in human milk; limited human evidence of increased incidence from worker study and drinking water
Urethane	More likely (HPV*, occupational, food)	Mammary tumorigen	Increased incidence of mammary carcinomas in mice and mammary tumors in hamsters.

* HPV – High Production Volume refers to chemicals produced in or imported into the U.S. in amounts over one million pounds per year.

Benzene: This volatile organic compound is widely used in chemical production; gasoline production, storage, transport, vending, and combustion; and is a by-product of other processes (e.g. coke ovens).¹ Some consumer products contain benzene, including carpet, pesticide products, and adhesive removers. Benzene is a toxic air contaminant monitored by the California Air Resources Board and is also a water contaminant of concern.

Exposure to benzene is highest in urban areas, in workplaces where there is heavy traffic or machinery, and around gasoline filling stations. Exposure also occurs by inhaling tobacco smoke (see Section I, Chapter A), drinking contaminated water, or eating contaminated food.¹ Benzene is a known human carcinogen by all routes of exposure, based on animal and human evidence. When administered orally, benzene caused mammary gland carcinomas and carcinosarcomas in female mice in four studies.¹

Ethylene oxide: Ethylene oxide is used to sterilize medical equipment and other products, such as foods, clothing, cosmetics, and beekeeping equipment. It is found in tobacco smoke, vehicle exhaust, and in some foods and spices. The general population may be exposed to ethylene oxide in tobacco smoke, ambient air pollution, or use of products that have been sterilized. Those who work with ethylene oxide are at greater risk of exposure to higher levels of the compound.

Two animal studies found a higher incidence of mammary tumors in mice exposed to lower doses than those exposed to higher doses (an inverse dose-response).¹ Ethylene oxide is a known

human carcinogen, but evidence of breast cancer risk from several occupational studies has been somewhat inconsistent. In an ethylene oxide-specific study, Norman et al. found about a two-fold increased risk of breast cancer (standardized morbidity ratio) in women who worked in a plant with documented exposure.⁹ Several studies have assessed risks in nursing and in health and science laboratories, which may involve exposures to ethylene oxide, but may also involve exposures to other risk factors, such as shift work and light at night (discussed in Section I, Chapter H). Many of the studies of nurses were well designed and findings for chemical exposures are unlikely to be confounded by established breast cancer risk factors. For example, Band et al. found an elevated risk for nurses in British Columbia (OR = 1.54; 95% CI = 1.05–2.28) and Gunnarsdottir et al. found similarly elevated risk.¹

Methylene chloride: Although this highly volatile compound was discontinued as a propellant for hair spray, it is still used in other consumer products such as fabric cleaners, paint strippers, wood sealant and stains, spray paints, adhesives, furniture and shoe polish, and art supplies.¹ Due to its common use and volatility, methylene chloride is ubiquitous in ambient air and ground water. Exposure occurs during production and industrial use of methylene chloride and of dichloromethane, and during the use of nearly 1,000 methylene chloride-containing consumer products.

Methylene chloride is a probable human carcinogen.¹⁰ High levels of methylene chloride have been associated with benign mammary tumors in rats, as well as an increase in the number

of mammary tumors per animal. Inhalation of methylene chloride increased the incidence of fibroadenomas of the mammary gland in female rats and appeared to do the same in male rats.¹

Styrene: This compound is used in and is a byproduct of polystyrene manufacturing (plastics labeled #6) and the synthetic rubber industry. It is present in a number of building materials and consumer products including carpets, paints, adhesives, hobby and craft supplies, and home maintenance products.^{1,2} Exposure is common in the general population from inhalation of ambient air and tobacco smoke, and consuming food that has been in contact with polystyrene.¹

Styrene is classified as a possible carcinogen.¹⁰ It has been associated with increased mammary tumors in some animal studies, but not consistently.¹ Human data on a possible relationship between styrene and breast cancer are limited, but at least one study reported elevated breast cancer mortality associated with occupational exposure to styrene based on death certificate data.¹¹

Tetrachloroethylene: The solvent tetrachloroethylene, also known as perchloroethylene or Perc, replaced the acutely toxic solvent carbon tetrachloride in dry cleaning. Exposure has occurred among workers, residents near dry cleaning facilities and through ingestion of contaminated water. Elevated levels of breast cancer have been found in women working in dry cleaning (OR = 5.25; 95% CI = 1.41–19.5).⁶

One population-based case-control study of women who were accidentally exposed to Perc leaching from improperly prepared water pipes

found an elevated risk of breast cancer associated with exposure, although the increase in risk was not monotonic (Adjusted OR = 1.6; 95% CI = 1.1–2.4 for exposure > 75th percentile).¹² Possible confounders were extensively evaluated and this “natural” experiment provided an unusual ability to define the exposed population.

Carbon tetrachloride: While no longer used in dry cleaning due to its acute toxicity, carbon tetrachloride may still be present in paint and varnish removers; and in cleaning, auto, and hobby products.¹ This compound is detected at low levels in ambient air and water, and has been detected in human breast milk.³ When administered by subcutaneous injection, carbon tetrachloride induced mammary adenocarcinomas and fibroadenomas in female rats.¹⁰

D5: Some dry cleaners are now replacing Perc with decamethylcyclotrisiloxane or D5, an unregulated solvent which is also used in personal care and automotive products.¹³ D5 is a common air contaminant,¹⁴ but there is little information about potential health effects. A recent study found that D5 was not hormonally active in estrogenic and androgenic assays.¹⁵

Toluene diisocyanate mixtures: These are highly reactive compounds used in the production of polyurethane foams and coatings; paints, varnishes, and sealants; and binders. Exposure to toluene diisocyanates from inhalation or dermal contact can occur in all phases of its manufacture and use.¹⁰ Household products employing polyurethane varnishes or foam such as furniture, carpet underlay, and bedding may volatilize unreacted toluene diisocyanates.¹ The FDA has determined that levels of toluene diisocyanates in

food, food additives, and food packaging are very low. In testing on female rats, these mixtures, administered by gavage, induced mammary gland fibroadenomas.¹

Urethane: This solvent is used on organic materials and as a co-solvent in the manufacture of pesticides, fumigants, and cosmetics, where workers may be exposed. Urethane also is naturally produced in fermented foods, such as beer, bread, wine, soy sauce, yogurt, and olives.¹ Exposure may occur by ingesting these foods and beverages.

When administered in drinking water, urethane induced mammary carcinomas in mice of both sexes, and mammary tumors in hamsters of both sexes.¹ When injected intraperitoneally, urethane increased incidence of mammary tumors in rats of both sexes. X-irradiation combined with administration of urethane led to the induction of mammary carcinomas in mice. Vinyl carbamate epoxide, a metabolite of urethane, causes mammary gland tumors.¹

Industrial Chemicals

Many industrial chemicals have been examined for their potential health effects. While these are more often a concern for workers, such compounds are often released during manufacturing or from end products. Table 2 provides a summary of the likelihood of exposure, biological mechanisms of concern and evidence of a link with breast cancer for selected industrial chemicals.

Acrylonitrile: This chemical has been detected only rarely and at low levels in ambient air and water.¹ The general population may be exposed from use of acrylic carpeting, rubber, and toys. Exposure from food containers is generally very low, because acrylonitrile monomers do not readily migrate.^{1,16} Administered orally, this chemical increased the incidence of mammary gland carcinomas in female and male rats. While inhalation studies in female rats found increased mammary tumors, at least one mouse study did not find an increase.

Table 2. Select Industrial Chemicals Linked to Breast Cancer.

Compound	Exposure Potential	Mechanism(s) of Concern	Human/Animal Evidence
Acrylonitrile	Less likely (air, water, consumer products, food)	Mammary tumorigen and carcinogen	Inconsistent – mammary gland tumors in rats, not mice
Isoprene	More likely (air, occupational)	Oxidation Tumorigen	Neoplasms of the mammary gland in both rats and mice
Nitrobenzene	Undefined (ambient air, consumer products, water)	Mammary tumorigen	Mammary gland tumors in at least one mouse species
Nonylphenols	More likely (HPV*, consumer products, water, food)	Endocrine disruption	Affects reproduction of aquatic species, accelerates rate of mammary gland development

* HPV – High Production Volume refers to chemicals produced in or imported into the U.S. in amounts over one million pounds per year.

Isoprene (2-methylbuta-1,3-diene): Isoprene is formed naturally in plants and animals, including humans (estimated at 17 mg/day for a 150 lb. person). Low levels of isoprene are common in many foods. The chloroplasts of certain tree species are a main source of isoprene, with especially high emissions (~5–20 mg/m²/hr) on hot, sunny days.¹⁰ About 95 percent of the isoprene manufactured is used to produce natural rubber. Sources of emissions include ethylene production by petroleum processing, wood pulping, oil fires, wood-burning stoves and fireplaces, other biomass combustion, tobacco smoke, gasoline, and exhaust from turbines and automobiles.¹ Workers involved in the manufacturing and use of isoprene in the 1940s and 1950s may have been exposed to high levels.¹⁷

While current engineering controls have increasingly reduced exposure, some isoprene is likely to be released during production of the original monomer and even more likely released during subsequent polymer production, so some workers are exposed.¹⁷

Isoprene is closely related to butadiene (see Section I, Chapter I.B, Air Pollutants), but its metabolism and chronic toxicity appear to differ.¹⁸ Isoprene is reasonably expected to be a human carcinogen based on evidence for carcinogenicity at multiple organ sites in both mice and rats exposed by inhalation.¹⁰ Inhalation exposure of rats to isoprene vapors induced increased incidence of neoplasms of the mammary gland. Common sites of neoplasm induction by isoprene and butadiene included the mammary gland in mice.¹ There is no epidemiologic evidence of

cancer among workers exposed to isoprene;¹⁹ no adequate human studies of isoprene exposure and cancer were identified.¹

Nitrobenzene: This compound is found in soaps and in shoe and metal polishes, and it is used in spray paints, floor polishes, the perfume industry, and as a substitute for almond essence. It is commonly detected in surface and ground water.¹ The general public may be exposed to nitrobenzene through inhalation of ambient air, ingestion of water, or dermal contact with products or water containing nitrobenzene.¹ Exposure to nitrobenzene caused mammary gland tumors in female B6C3F1 mice.

Nonylphenols

Nonylphenol is an organic chemical produced in large quantities in the U.S. for manufacturing nonylphenol ethoxylates, surfactants used in cleaning and other products, most notably laundry detergents.²⁰ Nonylphenols are often found in streams and waste water treatment plant effluent as a breakdown product from surfactants and detergents; they are persistent and do not readily degrade in water. The U.S. EPA is working with several companies to eliminate the intentional use of nonylphenol and nonylphenol ethoxylates in detergents.^{20, 21} Nonylphenol ethoxylates are also used in paper and pulp production, latex paints, pesticides, flotation agents, industrial and automobile cleaners, and in the textile industry.²² Besides the predominant use of nonylphenols for manufacturing nonylphenol ethoxylates, they are also used in the form of tris(nonylphenol)phosphites as antioxidants in plastics. Ethylene oxide (see above) is also used in nonylphenol ethoxylate production.

A German study found that nonylphenols were ubiquitous in food.²² Although nonylphenols are lipophilic, their concentration was not related to the fat content of the food or [to](#) the packaging, leading the authors to hypothesize that food contamination could be occurring at multiple stages of food production. The authors also hypothesized that nonylphenols may be breakdown products from cleaning agents or pesticides used in agriculture or processing, or may migrate into food from plastic packaging materials.

Although nonylphenol exposure appears ubiquitous, biological samples found measurable levels of nonylphenol in just over half of adults tested²³ and fewer than six percent of girls tested.²⁴ The relatively low frequency of detection of nonylphenol (compared, for example, to Bisphenol A) could be explained by a lower human exposure to nonylphenol, by different pharmacokinetic factors (i.e., absorption, distribution, metabolism, elimination), by the fact that 4-n-nonylphenol (the measured nonylphenol isomer) represents a small percentage of the nonylphenol used in commercial mixtures, or a combination of all of the above. Additional research is needed to determine the best urinary biomarker(s) to assess exposure to nonylphenol.²³

Nonylphenols are known to cause reproductive effects in aquatic organisms, with suspected effects on human endocrine, reproductive, and immune systems. Nonylphenols have been shown to be weakly estrogenic in human cell cultures and in vivo rat bioassays by competitively binding to the estrogen receptor.²² In rat models,

nonylphenols accelerated mammary gland development.²⁵

Amsonic acid: Like nonylphenols, amsonic acid is used in laundry detergents (as an optical brightener) and is also used in the manufacturing of dyes. Potential for human exposure to amsonic acid is quite possible from clothing, packaging materials, and foods such as fish; it is produced and used in great volume in the U.S. While little toxicologic or other information is available on amsonic acid, at least one animal study found a dose-related increase in mammary fibroadenomas.¹

Related Compounds

1,3-Butadiene is an industrial chemical used as a monomer in the production of synthetic rubber, generally mixed with styrene or acrylonitrile, both also shown to cause mammary gland tumors in animal studies.¹ It is a probable carcinogen and of particular concern for certain industries.

However, many of the studies to date have focused on styrene-butadiene rubber workers, who are exposed to both industrial chemicals. Because the most common route of exposure for the general population is inhalation from vehicle exhaust, this compound is discussed at greater length in Section I, Chapter B.1, Air Pollutants, Fuels and Additives.

Nitromethane is primarily used to synthesize derivatives used as pharmaceuticals, agricultural soil fumigants, and industrial antimicrobials. While the most common exposure sources are motor vehicle exhaust and tobacco smoke, exposure may occur from the use of solvents (manicuring preparations or rubber adhesives),

aerosol propellants, and fuels containing nitromethane.²⁶ Nitromethane has been detected in air, as well as ambient and drinking water.¹

Perfluorooctanoic acids are used in non-stick and stain-resistant coatings on rugs, furniture, clothes, cookware, fire-fighting applications, cosmetics, lubricants, paints, and adhesives. In the past, their use in insecticide and herbicide formulations resulted in direct releases into the environment. They are widely detected in blood samples in the US. Two studies demonstrate that perfluorooctanoic acid is a multi-site carcinogen. The single study that included females observed mammary gland tumors in female rats.¹ Perfluorooctanoic acids are discussed in Section I, Chapter B.2, Persistent Organic Pollutants.

Consumer Cleaning and Air Freshening Products

Some cleaning and air freshening products contain volatile organic compounds, such as glycol ethers and terpenes. The former are toxic air contaminants. The latter include terpene hydrocarbons, terpene alcohols, and related compounds which are often derived from pine, orange, and other plant oils, and used as scenting agents or as active solvents.²⁷ Terpenes react with ozone to form a variety of secondary pollutants. However, relatively little is known about the resulting indoor concentrations.²⁸ In addition to formaldehyde, the terpene-ozone reaction produces acetone and acetaldehyde (see Section I, Chapter B.1), the latter at much higher levels in the presence of nitrogen dioxide.²⁹ Exposure to these compounds is very likely, given the common use of cleaning products and air fresheners.²⁸

Conclusions and Future Directions

There are thousands of other organic solvents and industrial chemicals, some of which have not been adequately tested for carcinogenicity or endocrine disruption or other potential effects that might impact breast cancer risk. We lack information on the levels of exposure and relative contribution of various sources to our body burden. The fact that no one is exposed to just one of these chemicals at a time highlights our lack of understanding of possible additive effects, interactions or synergies. A single animal study was identified in this review that looked at a combination of exposures: urethane and x-irradiation, which led to the induction of mammary carcinomas in mice.¹

The Occupational Safety and Health Administration (OSHA) produces cancer risk estimates to determine permissible exposure limits (PEL) for their regulation of many of these compounds in workplaces, including ethylene oxide, benzene, methylene chloride, and 1,3-butadiene. While these risk estimates are not specific to breast cancer, the overall risks are as high as one percent³⁰ indicating that workers may face a substantial hazard.

While workers may have some of the highest exposures, occupational studies often face serious limitations. Breast cancer has a relatively long latency. It is difficult to estimate women's exposure. Employment records provide limited job histories because women's length of employment in a "usual" job may be short, and job exposure matrices have not been designed specifically to assess women's experiences, which may typically differ from men in the same job category. Many occupational exposures are

correlated: solvents are often correlated with each other, reducing researchers' ability to attribute risk to individual compounds or subgroups of compounds. When many occupations are analyzed, it is difficult to link job categories to specific exposures, interpret inconsistencies across jobs with overlapping exposures, and evaluate the role of chance. It is also difficult to assess consistency between the occupational studies, as job classifications are not often comparable from one study to another.

Finally, in addition to confounding specific to breast cancer, studies of occupational exposures may understate risk because of the "healthy worker effect" or because workers with sensitivity to the exposure leave due to acute or short-term illness (e.g., skin rashes or respiratory distress), so that they may not be included in long-term follow-up studies. If short-term workers are not included, and they develop cancers that were caused by their exposures, these may be missed and the true effect of the workplace exposures will be underestimated. Further work is needed in exposure assessment, toxicology, and susceptibility to make future epidemiologic studies more useful. One of the most promising lines of research would be an on-going study of a large number of exposed women workers, with government ensuring access to this population. There is an on-going Agricultural Health Study; we need something like this for industrial workers.

For nonylphenol and nonylphenol ethoxylate, work is needed to determine how exposure to these compounds disrupts the endocrine system, including determining the toxicologically active form(s) and the pharmacokinetics and

toxicokinetics of nonylphenols and metabolites. Other congeners in this group may also be of concern,²² but no data were identified, making this another area for possible study. Canada and the European Union have banned nonylphenol ethoxylates in detergents, and the Sierra Club has called for similar action in the U.S.³¹

While formaldehyde and acetaldehyde are important indoor toxicants, little is known about the toxicology of many terpenoid oxidation products. Several reaction pathways involving ozone and reactive compounds that are present in the formulation of household products are still not well characterized and deserve further attention.

References

1. Rudel RA, Attfield KR, Schifano JN, Brody JG. Chemicals causing mammary gland tumors in animals signal new directions for epidemiology, chemicals testing, and risk assessment for breast cancer prevention. *Cancer*. 2007, 109(S12):2635-66.
2. Brody JG, Moysich KB, Humblet O, Attfield KR, Beehler GP, Rudel RA. Environmental pollutants and breast cancer: epidemiologic studies. *Cancer*. 2007, 109(12 Suppl):2667-711.
3. Labreche FP, Goldberg MS. Exposure to organic solvents and breast cancer in women: a hypothesis. *Am J Ind Med*. 1997, 32(1):1-14.
4. Brody JG, Rudel RA, Michels KB, Moysich KB, Bernstein L, Attfield KR, Gray S. Environmental pollutants, diet, physical activity, body size, and breast cancer: where do we stand in research to identify opportunities for prevention? *Cancer*. 2007, 109(S12):2627-34.
5. Hansen J. Breast cancer risk among relatively young women employed in solvent-using industries. *Am J Ind Med*. 1999, 36(1):43-7.
6. Band PR, Le ND, Fang R, Deschamps M, Gallagher RP, Yang P. Identification of occupational cancer risks in British Columbia. A population-based case-control study of 995 incident breast cancer cases by menopausal status, controlling for confounding factors. *J Occup Environ Med*. 2000, 42(3):284-310.
7. Ray RM, Gao DL, Li W, Wernli KJ, Astrakianakis G, Seixas NS, Camp JE, Fitzgibbons ED, Feng Z, Thomas DB, Checkoway H. Occupational exposures and breast cancer among women textile workers in Shanghai. *Epidemiology*. 2007, 18(3):383-92.
8. Peplonska B, Stewart P, Szeszenia-Dabrowska N, Rusiecki J, Garcia-Closas M, Lissowska J, Bardin-Mikolajczak A, Zatonski W, Gromiec J, Brzezniacki S, Brinton LA, Blair A. Occupation and breast cancer risk in Polish women: a population-based case-control study. *Am J Ind Med*. 2007, 50(2):97-111.
9. Norman SA, Berlin JA, Soper KA, Middendorf BF, Stolley PD. Cancer incidence in a group of workers potentially exposed to ethylene oxide. *Int J Epidemiol*. 1995, 24(2):276-84.
10. National Toxicology Program (NTP). Report on Carcinogens (RoC). 11th ed. Research Triangle Park, NC, USA: United States Department of Health and Human Services (DHSS), National Toxicology Program, 2005. Available at <http://ntp.niehs.nih.gov/ntpweb/index.cfm?objectid=035E5806-F735-FE81-FF769DFE5509AF0A>.
11. Cantor KP, Stewart PA, Brinton LA, Dosemeci M. Occupational exposures and female breast cancer mortality in the United States. *J Occup Environ Med*. 1995, 37(3):336-48.

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12. Aschengrau A, Rogers S, Ozonoff D. Perchloroethylene-contaminated drinking water and the risk of breast cancer: additional results from Cape Cod, Massachusetts, USA. *Environ Health Perspect.* 2003, 111(2):167-73.
13. Quint J. Relating occupational and environmental settings in biomonitoring. Presented at the University of California BSBRP, Meeting on Designing State Biomonitoring; Berkeley, CA, USA. Berkeley, CA, USA: University of California, Berkeley, 2007.
14. Zhang Z, Guo B, Zhang JS. Determination of volatile organic compounds in residential buildings [conference proceeding]. Presented at the International Conference on Indoor Air Quality Problems and Engineering Solutions; Research Triangle Park, NC, USA. Syracuse, NY, USA: Syracuse University, Building Energy and Environmental Systems Laboratory, 2003. Available at http://energysystems.syr.edu/pdf/Residential%20environment-IAQSymposium_zhibinzhang-Final.pdf.
15. Quinn AL, Regan JM, Tobin JM, Marinik BJ, McMahon JM, McNett DA, Sushynski CM, Crofoot SD, Jean PA, Plotzke KP. In vitro and in vivo evaluation of the estrogenic, androgenic, and progestagenic potential of two cyclic siloxanes. *Toxicol Sci.* 2007, 96(1):145-53.
16. Leber AP. Human exposures to monomers resulting from consumer contact with polymers. *Chem Biol Interact.* 2001, 135-136:215-20.
17. Lynch J. Occupational exposure to butadiene, isoprene and chloroprene. *Chem Biol Interact.* 2001, 135-136:207-14.
18. Bird MG, Rice JM, Bond JA. Evaluation of 1,3-butadiene, isoprene and chloroprene health risks. *Chem Biol Interact.* 2001, 135-136:1-7.
19. Rice JM, Boffetta P. 1,3-Butadiene, isoprene and chloroprene: reviews by the IARC monographs programme, outstanding issues, and research priorities in epidemiology. *Chem Biol Interact.* 2001, 135-136:11-26.
20. United States Environmental Protection Agency (US EPA). Safer Detergents Stewardship Initiatives (SDSI) [web page]. Washington, DC, USA: United States Environmental Protection Agency (US EPA), 2007. Available at <http://www.epa.gov/dfe/pubs/projects/formulat/sdsi.htm>. Accessed 24 Aug 2007.
21. Proctor & Gamble. Nonylphenol and Nonylphenol Ethoxylates and P&G Products. In. *P&G Perspectives*. Cincinnati, OH, USA: Proctor & Gamble, 2005. Available at http://www.pgperspectives.com/en_UK/productingredient/nonylphenolnonylphenolethoxylates_en.html.
22. Guenther K, Heinke V, Thiele B, Kleist E, Prast H, Raecker T. Endocrine disrupting nonylphenols are ubiquitous in food. *Environ Sci Technol.* 2002, 36(8):1676-80.

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23. Calafat AM, Kuklennyik Z, Reidy JA, Caudill SP, Ekong J, Needham LL. Urinary concentrations of bisphenol A and 4-nonylphenol in a human reference population. *Environ Health Perspect.* 2005, 113(4):391-5.
24. Wolff MS, Teitelbaum SL, Windham G, Pinney SM, Britton JA, Chelimo C, Godbold J, Biro F, Kushi LH, Pfeiffer CM, Calafat AM. Pilot study of urinary biomarkers of phytoestrogens, phthalates, and phenols in girls. *Environ Health Perspect.* 2007, 115(1):116-21.
25. Fenton SE. Early life exposures to environmental compounds: lessons learned from animal models. *The Ribbon - A Newsletter of the Cornell University Program on Breast Cancer and Environmental Risk Factors (BCERF).* 2007, 12(1):1-4.
26. World Health Organization (WHO), International Agency for Research on Cancer (IARC). NITROMETHANE (Group 2B) CAS No.: 75-52-5, Vol 77, p. 487. On: International Programme on Chemical Safety (IPCS). INCHEM: Chemical Safety Information from Intergovernmental Organizations -- Summaries & Evaluations. Lyon, France: World Health Organization (WHO), 2000. Available at <http://www.inchem.org/documents/iarc/vol77/77-15.html>.
27. Singer BC, Destailats H, Hodgson AT, Nazaroff WW. Cleaning products and air fresheners: emissions and resulting concentrations of glycol ethers and terpenoids. *Indoor Air.* 2006, 16(3):179-91.
28. Destailats H, Lunden MM, Singer BC, Coleman BK, Hodgson AT, Weschler CJ, Nazaroff WW. Indoor secondary pollutants from household product emissions in the presence of ozone: A bench-scale chamber study. *Environ Sci Technol.* 2006, 40(14):4421-8.
29. Nazaroff WW, Coleman BK, Destailats H, Hodgson AT, Liu DL, Lunden MM, Singer BC, Weschler CJ. *Indoor Air Chemistry: Cleaning Agents, Ozone and Toxic Air Contaminants -- Final Report: Contract No. 01-336.* Sacramento, CA, USA: California Air Resources Board, 2006. Available at http://www.arb.ca.gov/research/apr/past/01-336_a.pdf.
30. United States Federal Register. Reference Pending. 2006.
31. Hoponick J. *Nonylphenol Ethoxylates: A Safer Alternative Exists to This Toxic Cleaning Agent.* Washington, DC, USA: Sierra Club, 2005. Available at http://www.sierraclub.org/toxics/nonylphenol_ethoxylates3.pdf.