Cancer Association of South Africa (CANSA)

Fact Sheet on Volatile Organic Compounds

Introduction

Organic compounds are chemicals that contain carbon and are found in all living things. Many volatile organic compounds are classified as known or possible carcinogens, irritants and toxicants. Volatile organic compounds, sometimes referred to as VOCs, are organic compounds that easily become vapours or gases. Along with carbon, they contain elements such as hydrogen, oxygen, fluorine, chlorine, bromine, sulphur or nitrogen.

[Picture Credit: Volatile Organic Compounds]

VOCs are organic chemicals that have a high vapour pressure at ordinary room temperature. Their high vapour pressure results from a low boiling point, which causes large numbers of molecules to evaporate or sublimate from the liquid or solid form of the compound and enter the surrounding air, a trait known as volatility.

Volatile organic compounds are released from burning fuel, such as gasoline (petrol), wood, coal, or natural gas. They are also emitted from oil and gas fields and diesel exhaust. They are also released from solvents, paints, glues, and other products that are used and stored at home and at work.

Examples of volatile organic compounds are petrol, benzene, formaldehyde, solvents such as toluene and xylene, styrene, and perchloroethylene (or tetrachloro-ethylene), the main solvent used in dry cleaning.

Many volatile organic compounds are commonly used in paint thinners, lacquer thinners, moth repellents, air fresheners, hobby supplies, wood preservatives, aerosol sprays, degreasers, automotive products, and dry cleaning fluids.

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Whether it is paints (water-based or solvent-based), cosmetics, disinfectants, glue, ink for printers, marker pens, tobacco smoke or petrol from one's lawnmower, volatile organic compounds (VOC) are present in some of these items commonly used at home. Exposure to VOC's can cause both immediate and long term effects.

VOCs are numerous, varied, and ubiquitous. They include both human-made and naturally occurring chemical compounds. Most scents or odours are of VOCs. VOCs play an important role in communication between plants, and messages from plants to animals. Some VOCs are dangerous to human health or cause harm to the environment. Anthropogenic (originating in human activity) VOCs are regulated by law, especially indoors, where concentrations are the highest. Harmful VOCs typically are not acutely toxic, but have compounding long-term health effects. Because the concentrations are usually low and the symptoms slow to develop, research into VOCs and their effects is difficult.

Hwang, J.B., Leei, S., Yeum, J., Kim, M., Choi, J.C. Park, S-J. & Kim, J. 2019.
"A simultaneous headspace-gas chromatography/mass spectrometry (HS-GC/MS) method was developed and validated to determine the migration of 12 volatile organic compounds (methanol, acetone, methylethylketone, ethylacetate, isopropylalcohol, benzene, toluene, ethylbenzene, xylene, cumene, propylbenzene, and styrene) from food contact materials into food simulants (water, 4% acetic acid, 50% ethanol, and n-heptane). The limits of detection and quantification were 0.007-0.201 mg L^{-1} and 0.023-0.668 mg L^{-1}, respectively. The method was applied to 205 samples of paper/paperboard, polyethylene, polypropylene, polystyrene, and polyethylene terephthalate. The estimated daily intake (EDI) was calculated using the migration results. Exposure assessments were carried out to compare the EDI to the tolerable daily intake (TDI); the results indicated that the EDI of styrene represented only a small percentage (8.0%) of the TDI. This analytical method will be a useful tool to examine levels of various volatile compounds migrating from food packaging to food simulants using HS-GC/MS method."

Products used at home or work that can release VOCs into the air when used and stored

Examples of Household Products	Possible VOC Ingredients
Fuel containers or devices using gasoline, kerosene, fuel oil and products with petroleum distillates: paint thinner, oil-based stains and paint, aerosol or liquid insect pest products, mineral spirits, furniture polishes	BTEX (benzene, toluene, ethylbenzene, xylene), hexane, cyclohexane, 1,2,4-trimethylbenzene
Personal care products: nail polish, nail polish remover, colognes, perfumes, rubbing alcohol, hair spray	Acetone, ethyl alcohol, isopropyl alcohol, methacrylates (methyl or ethyl), ethyl acetate
Dry cleaned clothes, spot removers, fabric/ leather cleaners	Tetrachloroethene (perchloroethene (PERC), trichloroethene (TCE))
Citrus (orange) oil or pine oil cleaners, solvents and some odour masking products	d-limonene (citrus odour), a-pinene (pine odour), isoprene
PVC cement and primer, various adhesives, contact cement, model cement	Tetrahydrofuran, cyclohexane, methyl ethyl ketone (MEK), toluene, acetone, hexane, 1,1,1-trichloroethane, methyl-iso-butyl ketone (MIBK)
Paint stripper, adhesive (glue) removers	Methylene chloride, toluene, older products may contain carbon tetrachloride

Degreasers, aerosol penetrating oils, brake cleaner, carburettor cleaner, commercial solvents, electronics cleaners, spray lubricants	Methylene chloride, PERC, TCE, toluene, xylenes, methyl ethyl ketone, 1,1,1-trichloroethane
Moth balls, moth flakes, deodorizers, air fresheners	1,4-dichlorobenzene, naphthalene
Refrigerant from air conditioners, freezers, refrigerators, dehumidifiers	Freons (trichlorofluoromethane, dichlorodifluoromethane)
Aerosol spray products for some paints, cosmetics, automotive products, leather treatments, pesticides	Heptane, butane, pentane
Upholstered furniture, carpets, plywood, pressed wood products	Formaldehyde

Common Volatile Organic Compounds (VOCs) in the Home
The most common indoor VOC emission sources include consumer products (e.g., cleaners, solvents, mothballs), building materials (e.g., floor and wall coverings, carpet, insulation, paint, wood finishing products), combustion processes (e.g., smoking, cooking, home heating), personal care products (e.g., shampoo, soaps), attached garages, dry-cleaned clothing, and municipal tap water. Products can release VOCs while using them, and, to some degree, when they are stored.

Volatile Organic Compounds (VOCs) found in Household Products:

- Paints (both water-based and solvent-based), paint strippers and other solvents
- wood preservatives
- aerosol sprays
- cleansers and disinfectants
- moth repellents and air fresheners
- stored fuels and automotive products
- hobby supplies
- dry-cleaned clothing
- pesticide

Other products, including:

- building materials and furnishings
- office equipment such as copiers and printers, correction fluids and carbonless copy paper
- graphics and craft materials including glues and adhesives, permanent markers and photographic solutions.

(Myatt, 2015).

Norris, C., Fang, L., Barkioh, K.K. Carlson, D., Zhang, Y., Mo, J., Li, |., Zhang, J., Cui, X., Schauer, J.J., Davis, A., Black, M. & Bergin, M.H. 2019.
"Air pollution in China is an ongoing concern, with subsets of the population (e.g., asthmatic children) especially susceptible to the associated health effects. In addition, people spend the majority of their time indoors, where pollutant composition may differ from the better characterized ambient environment. Although volatile organic compounds (VOCs) present health risks and have high concentrations indoors, their sources have not been thoroughly quantified in typical homes in

suburban China. Similarly lacking is an understanding of how well a purifier with high efficiency particulate air and activated carbon filters can remove VOCs in a real-world setting in China. In this study, we a) quantified total VOCs (TVOC) and 900 + individual VOCs in 20 homes in China, b) identified potential sources of VOCs, and c) evaluated impacts of filtration. We used non-negative matrix factorization, a variable reduction technique, to identify sources. TVOC and individual compounds had higher concentrations indoors than outdoors (mean [range] indoors, filtration with pre-filter only: 302 [56-793] µg m^{-3}; outdoors, entire study: 92 [26-629] µg m^{-3}), indicating prevalent sources indoors. Many compounds detected have not, to our knowledge, been measured in homes in China. Some compounds (e.g., octanal, heptanal, α-cedrene) were specific to the indoor environment, a few were ubiquitous (e.g., acetaldehyde, formaldehyde), and others were detected infrequently. These compounds may originate from consumer products, solvents, vehicle emissions, a hexane source, wooden products, and cooking. Filtration may improve air quality indoors by lowering concentrations of some VOCs, and, specifically, contributions related to solvents and consumer products."

Harmful Volatile Organic Compounds (VOCs)

Known harmful Volatile Organic Compounds (VOCs) include:

Volatile Organic Compound	Sources	Health Effect
Acrolein	Burning of organic matter. Tobacco smoke. Combustion of petrol. Combustion of biodiesel.	Causes DNA damage in p53 tumour suppression genes. Inhibits DNA repair.
Naphthalene	Pesticides (moth balls).	Reasonably anticipated to be a human carcinogen.
Paradichlorobenzene	Pesticides (moth crystals). Toilet bowl deodorizer. Room deodorizers.	Irritation of the skin, throat, and eyes. Effects on the liver, skin, and central nervous system (CNS). Causes kidney tumours in male rats and liver tumours in both sexes of mice. Classified as possible human carcinogen.
Acetaldehyde	Tobacco smoke. Water-based paint. Unvented combustion appliances. Leakage from wood stoves, furnaces, and fireplaces.	Acetaldehyde is highly toxic, mutagenic and carcinogenic.
Benzene	Tobacco smoke. Some furnishings Paints Coatings Wood products. Stored gasoline. Vehicle operation. Evaporation from hot engines in attached garages.	Benzene is a well-established cause of cancer in humans. The International Agency for Research on Cancer has classified benzene as carcinogenic to humans (Group 1). Chronic exposure to benzene can reduce the production of both red and white blood cells from bone marrow in humans, resulting in aplastic anaemia. Both B-cell proliferation and T-cell proliferation are reduced by benzene. Benzene is a moderate eye irritant and a skin irritant. Acute occupational exposure to benzene may cause narcosis: headache, dizziness, drowsiness, confusion, tremors and loss of consciousness.2 Use of alcohol enhances the toxic effect.
Formaldehyde	Some manufactured wood products used as building materials, in cabinets, and in furniture, e.g., medium density fibreboard, particle board. Plywood with urea formaldehyde resin. Urea formaldehyde foam insulation (no longer used but still present in some buildings). Tobacco smoke. Unvented combustion appliances. Personal care products.	IARC has concluded that formaldehyde is "**carcinogenic** to humans" based on higher risks of nasopharyngeal cancer and leukaemia

Acrylonitrile	Manufacture of acrylic and modacrylic fibres. Raw material in the manufacture of plastics (acrylonitrile-butadiene-styrene and styrene-acrylonitrile resins), adiponitrile, acrylamide, and nitrile rubbers and barrier resins.	Suspected human carcinogen Genotoxic Causes tumours in rats
1,3-Butadiene	Large amounts of 1,3-butadiene are released into the air by industrial sources. Automobile exhaust is a constant source of 1,3-butadiene release into the air. Cigarette smoke. Smoke of wood fires. Forest fires.	There is sufficient evidence in humans for the carcinogenicity of 1,3-butadiene. 1,3-Butadiene causes cancer of the haematolymphatic organs. There is sufficient evidence for the carcinogenicity of 1,3-butadiene in experimental animals. There is sufficient evidence for the in experimental animals. There is strong evidence that the carcinogenicity of 1,3-butadiene in humans operates by a genotoxic mechanism that involves formation of reactive epoxides, interaction of these direct acting mutagenic epoxides with DNA, and resultant mutagenicity. The metabolic pathways for 1,3-butadiene in experimental animals have also been demonstrated in humans. 1,3-Butadiene is carcinogenic to humans (Group 1)
Ethylene oxide	Release to air from some agricultural fumigation. Car exhaust.	Under the Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2005), ethylene oxide is carcinogenic to humans by the inhalation route of exposure, based on strong, but less than conclusive on its own, epidemiological evidence of lymphohaematopoietic cancers and breast cancer in EtO exposed workers, extensive evidence of carcinogenicity in laboratory animals, including lymphohaematopoietic cancers in rats and mice and mammary carcinomas in mice following inhalation exposure, clear evidence that EtO is genotoxic and sufficient weight of evidence to support a mutagenic mode of action for EtO carcinogenicity, and strong evidence that the key precursor events are anticipated to occur in humans and progress to tumours, including evidence of chromosome damage in humans exposed to EtO.
Propylene oxide	Adhesives and sealant chemicals. Flame retardants. Fuels and fuel additives. Viscosity adjustors. Anti-Freeze Products. De-icing Products. Laundry and dishwashing products.	Propylene oxide is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals.
Nicotine-derived nitrosamine ketone (**NNK**)	Tobacco smoke.	Metabolically activated NNK and NNN induce deleterious mutations in oncogenes and tumour suppression genes by forming DNA adducts, which could be considered as tumour initiation.
N-Nitrosodimethylamine (NDMA)	Tobacco smoke. Ingesting food that contains nitrosamines, such as smoked or cured meats and fish. Ingesting food that contains alkylamines, which can cause NDMA to form in the stomach. Drinking contaminated water. Drinking malt beverages (such as beer and whiskey) that may contain low levels of nitrosamines formed during processing. Using toiletry and cosmetic products such as shampoos and cleansers that contain NDMA. Workplace exposure can occur at tanneries, pesticide manufacturing plants and rubber and tire plants.	It is toxic to the liver and other organs Is a suspected human carcinogen
Vinyl chloride	Vinyl chloride is a chemical intermediate, not a final product.	The International Agency for Research on Cancer has determined that vinyl chloride is carcinogenic to people

	Vinyl chloride is used in the manufacture of numerous products in building construction, automotive industry, electrical wire insulation and cables, piping, industrial and household equipment, medical supplies, and is depended upon heavily by the rubber, paper, and glass industries.	EPA has determined that vinyl chloride is a human carcinogen.
Carbon tetrachloride	Found in cleaning fluid (in industry and dry cleaning establishments as a degreasing agent**.** In households as a spot remover for clothing, furniture, and carpeting.	The International Agency for Research on Cancer (IARC) has determined that carbon tetrachloride is possibly carcinogenic to humans The EPA determined that carbon tetrachloride is a probable human carcinogen
1,2-dichloroethane	Used to produce vinyl chloride monomer (VCM, chloroethene), the major precursor for PVC production. Used generally as an intermediate for other organic chemical compounds.	1,2-Dichloroethane is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals
Trichloroethylene	As a solvent to remove grease from metal parts A chemical that is used to make other chemicals, especially the refrigerant, HFC-134a. Solvent for a variety of organic materials. Used as a dry cleaning solvent.	There is sufficient evidence in humans for the carcinogenicity of trichloroethylene. Trichloroethylene causes cancer of the kidney. A positive association has been observed between exposure to trichloroethylene and non-Hodgkin lymphoma and liver cancer There is sufficient evidence in experimental animals for the carcinogenicity of trichloroethylene Trichloroethylene is carcinogenic to humans (Group 1)
Chloroform	Produced on a large scale as a precursor to Polytetrafluoroethylene (PTFE**)** – to make Teflon. It is also a precursor to various refrigerants.	Chloroform is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals
Carbon tetrachloride	Used as a solvent for oils, fats, lacquers, varnishes, rubber waxes, and resins, and a starting material in the manufacturing of organic compounds.	Exposure carbon tetrachloride can damage the liver, kidneys, and nervous system Carbon tetrachloride can cause cancer in animals Carbon tetrachloride is possibly carcinogenic to humans

(St Helen, et al., 2015; Koerselman & van der Graaf; World Health Organization; IARC; United States Environmental Protection Agency; National Toxicology Program, Department of Health and Human Services; Xue, *et al*., 2014; Wikipedia; Agency for Toxic Substances & Diseases Registry; Berkeley Lab).

Omidi, F., Dehghani, F., Fallahzadeh, R.A., Miri, M., Taghavi, M. & Eynipour, A. 2019.
"In this study, occupational exposure to volatile organic compounds (VOCs) in the rendering plant of poultry slaughterhouse was determined and subsequently, carcinogen and non-carcinogenic risks were assessed using the US Environmental Protection Agency (USEPA). National Institute for Occupational Safety and Health (NIOSH) methods of 1501 and 1600 were used to measure VOCs in the breathing zone of the workers. Samples were analyzed by GC/MS. Carcinogenic and non-carcinogenic risks and sensitivity analysis were carried out using Monte Carlo simulations technique. The concentration of benzene and CS_2 was higher than the occupational exposure limits (OEL). The hazard quotient (HQ) values for all measured compounds was more than 1, which indicating the high potential for non-carcinogenic risks. Furthermore, the calculated Lifetime Cancer Risks (LCR) for carcinogenic compounds revealed that cancer risk due to benzene is higher than the maximum acceptable level provided by USEPA (10^{-6}). Based on the sensitivity analysis, the concentration and exposure frequency are the most important variable influencing both carcinogen and non-carcinogenic risks. Therefore, the concentration levels of the VOCs and exposure frequency should be controlled using engineering control measures."

Other Health Effects of Volatile Organic Compounds (VOCs)
Health effects may include:

- eye, nose and throat irritation
- headaches, loss of coordination and nausea
- damage to liver, kidney and central nervous system
- some organics can cause cancer in animals, some are suspected or known to cause cancer in humans.

Key signs or symptoms associated with exposure to VOCs include:

- conjunctival irritation
- nose and throat discomfort
- headache
- allergic skin reaction
- dyspnoea (difficult breathing)
- declines in serum cholinesterase levels
- nausea
- emesis (vomiting)
- epistaxis (nose bleeds)
- fatigue
- dizziness

The ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect.

As with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed. Among the immediate symptoms that some people have experienced soon after exposure to some organics include:

- eye and respiratory tract irritation
- headaches
- dizziness
- visual disorders and memory impairment

Everson, F., De Boever, P., Nawrot, T.S., Goswami, N., Mthethwa, M., Webster, I., Martens, D.S., Mashele, N. Chariania, S., Kamau, F. & Strijdom, H. 2019.
"Exposure to ambient NO_2 and benzene, toluene ethyl-benzene and m+p- and o-xylenes (BTEX) is associated with adverse cardiovascular effects, but limited information is available on the effects of personal exposure to these compounds in South African populations. This 6-month follow-up study aims to determine 7-day personal ambient NO_2 and BTEX exposure levels via compact passive diffusion samplers in female participants from Cape Town, and investigate whether exposure levels are associated with cardiovascular risk markers. Overall, the measured air pollutant exposure levels were lower compared to international standards. NO_2 was positively associated with systolic and diastolic blood pressure (SBP and DBP), and inversely associated with the central retinal venular equivalent (CRVE) and mean baseline brachial artery diameter. o-xylene was associated with DBP and benzene was strongly associated with carotid intima media thickness (cIMT). Our findings showed that personal air pollution exposure, even at relatively low levels, was associated with several markers of cardiovascular risk in women residing in the Cape Town region."

Heaton, T., Hurst, L.K., Amiri, A., Lungu, C.T. & Oh, J. 2019.
"In the United States, there are more than 120,000 nail salons in which workers could be potentially exposed to a number of volatile organic compounds (VOCs) used in various procedures. Measuring workers exposure in the field is time-consuming and could be very expensive. The purpose of this study was to estimate the VOC levels in the proximity of workers in nail salons through simulating the application process of some popular nail polishes in a laboratory chamber. The worst-case scenario was defined as a worker's exposure during nail polish application to one set of fingernails every 15 minutes for an 8-hour shift (total nail sets = 32). Nail polish was applied on paper plates in a flow-controlled test chamber. Air was sampled during the application of five different nail polishes for 8 hours using passive air samplers and the experiment was triplicated. Passive samplers were used for VOCs and formaldehyde. In this worst-case scenario setting, a total of 17 VOCs were detected, with eight that were found in all the samples. The mean concentration of butyl acetate (161-330 ppm, parts per million) and ethyl acetate (440 ppm) exceeded the threshold limit value (TLV) of 150 ppm and 400 ppm, respectively. Formaldehyde was analyzed separately and the mean concentrations exceeded the TLV of 0.10 ppm in all types of nail polish, ranging from 0.12 ppm to 0.22 ppm. Occupational safety and health professionals could use these data to increase awareness of workers' potential exposure to high levels of VOCs in nail salons and recommend practical measures to reduce potential exposures."

Reducing the Risk of Exposure to Volatile Organic Compounds (VOCs)

- Avoid the use of air fresheners and room deodorizers, as these can result in eye, nose and throat irritation
- Select products that emit low or no VOCs when choosing new carpets, flooring, office furniture and paints.
- Choose low-VOC-emitting cleaners.
- Do not store chemical products in equipment rooms where they could contaminate the heating, ventilation and air-conditioning system.

Liu, C-Y., Tseng, C-H., Wang, H-C., Dai, C-F. & Shih, Y-H. 2019.
"This study examined the use of high dosages of ultraviolet germicidal irradiation (UVGI) (253.7 nm) to deal with various concentrations of air pollutants, such as formaldehyde (HCHO), total volatile organic compounds (TVOC), under various conditions of humidity. A number of irradiation methods were applied for various durations in field studies to examine the efficiency of removing HCHO, TVOC, bacteria, and fungi. The removal efficiency of air pollutants (HCHO and bacteria) through long-term exposure to UVGI appears to increase with time. The effects on TVOC and fungi concentration were insignificant in the first week; however, improvements were observed in the second week. No differences were observed regarding the removal of HCHO and TVOC among the various irradiation methods in this study; however significant differences were observed in the removal of bacteria and fungi."

Santos-Clotas, E., Cabrera-Codony, A., Boada, E., Gich, F., Muñoz, R. & Martin, M.J. 2019.
"The removal of siloxanes (D4 and D5) and volatile organic contaminants (hexane, toluene and limonene) typically found in sewage biogas was investigated in a lab-scale biotrickling filter (BTF) packed with lava rock under anoxic conditions. Complete removal efficiencies for toluene and limonene were recorded at all empty bed residence time (EBRT) tested. The influence of EBRT was remarkable on the abatement of D5, whose removal decreased from 37% at 14.5 min to 16% at 4 min, while the removal of D4 and hexane remained below 16%. The packing material was

supplemented with 20% of activated carbon aiming at increasing the mass transfer of the most hydrophobic pollutants. This strategy supported high removal efficiencies of 43 and 45% for hexane and D5 at the lowest EBRT. CO_2 and silica were identified as mineralization products along with the presence of metabolites in the trickling solution such as dimethylsilanediol, 2-carene and α-terpinene."

Medical Disclaimer

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