Citizen's Guide to

VOLATILE SYNTHETIC ORGANIC CHEMICALS IN DRINKING WATER

COMMONWEALTH OF PENNSYLVANIA
Department of Environmental Protection
Edward G. Rendell, Governor
Kathleen A. McGinty, Secretary
For more information, visit DEP's website at
www.dep.state.pa.us, Keyword: "DEP Drinking Water."

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Introduction

This *Citizen's Guide* explains how users of public water systems are protected from volatile synthetic organic chemical (VOC) contamination. It also explains how consumers of individual (private) water supplies can assess the safety of their water and, if necessary, reduce their exposure to VOCs.

VOCs are man-made substances that tend to evaporate (volatilize) when exposed to air. People are most commonly exposed to VOCs through the air, in food, through skin contact, and potentially from drinking water supplies. These chemicals are commonly used as solvents, degreasers, cleaning solutions, dry cleaning fluids and ingredients in pesticides and plastics. VOCs find their way into public and private water systems through accidental spills, runoff and improper disposal of some industrial, agricultural and domestic wastes. VOCs have been found in both surface (i.e., rivers, lakes) and ground (i.e., wells) drinking water supplies. When VOCs are found in groundwater, higher levels are usually detected. In contrast, VOCs found in surface water are usually detected at lower levels because VOCs tend to evaporate readily or are broken down by sunlight.

The United States Environmental Protection Agency currently regulates 21 VOCs. All public water systems must comply with the maximum contaminant levels (MCLs) for the 21 VOCs in this guide.

The Department of Environmental Protection (DEP) does not have the authority to regulate individual water systems. However, as a service to the public, DEP staff will interpret and evaluate the results of samples collected from private, individual water systems. Enforceable contaminant limits do not exist for individual water systems.

Fact sheets for the regulated 21 VOCs most commonly detected in surface and groundwater have been included in this *Guide*. These fact sheets provide a brief summary of how each chemical is normally used, health effects information, and methods of removing VOCs from drinking water.

Safety of Public Water Systems

Regulated Public Water Systems

DEP regulates public water systems (PWS), which are defined as systems that provide water to the public for human consumption and have at least 15 service connections or regularly serve an average of at least 25 individuals daily at least 60 days out of the year. Regulated systems are either community water systems or noncommunity water systems. A community water system is a PWS serving a residential population such as a municipality, mobile home park or nursing home. A noncommunity system serves a nonresidential population such as a restaurant, campground or factory.

To ensure that PWSs are complying with drinking water quality standards and conducting appropriate water quality compliance monitoring, DEP staff perform a variety of surveillance activities. These activities can include sanitary surveys and inspections of systems, assessments of the vulnerability of water sources to contamination and the development of programs to protect the quality of water sources.

The U. S. Environmental Protection Agency (EPA) developed drinking water quality standards, or MCLs, for the VOCs described in this guide. DEP adopted these standards, which are currently in effect in Pennsylvania.

MCL Development Process

Risk Assessment

Standards limiting the concentration of contaminants in public drinking water have been developed to protect the consumer from possible short-term and long-term adverse health effects. Contaminants are usually selected for regulation based on potential health risks and their occurrence or potential occurrence in drinking water.

The first phase of the extensive standard development procedure requires that each contaminant go through a risk assessment process. A complete contaminant risk assessment consists of these four steps:

The first step is **hazard identification**, or a determination of whether a chemical causes an adverse health effect. This is accomplished through gathering and evaluating data. The types of data include (a) the types of health injury or disease that might be produced by a chemical, and (b) the conditions of exposure that might produce injury or disease.

This data is obtained through animal and epidemiological studies. Lifetime animal studies are the primary method used for determining the carcinogenic and noncarcinogenic properties of a substance with the assumption that effects in humans can be inferred from effects in animals.

The second step is **dose-response assessment**, or a determination of the relationship between the amount of exposure to a chemical and an adverse health effect. Dose response is normally established through animal studies.

The third step is **human exposure assessment**, or a determination of past, current and anticipated human exposure to a chemical. This process involves estimating the number of people exposed to a substance and the magnitude, duration, and timing of the exposure.

The fourth step is **risk characterization**, or a determination of the possibility that humans will experience adverse health effects. This step involves combining the information from the first three steps to determine the likelihood that humans will experience any of the various forms of toxicity associated with a substance.

Determining an MCL--General Information

After the risk assessment process is completed, a maximum contamination level goal (MCLG) is determined for the tested contaminant. The MCLG is a level at which no known or anticipated adverse health effects occur and which allows an adequate margin of safety.

During the second phase of standards development, an MCL is established for the contaminant by setting it as close to the MCLG as is feasible. The MCL is considered feasible if the best available water treatment technology can efficiently remove the contaminant to or below the MCL level, and if laboratories are able to analyze for the contaminant at this level or lower with available methods. When

EPA evaluates treatment for removal of a particular contaminant from drinking water, it considers the following issues: commercial availability, removal efficiencies, treatment compatibility, reliability, economic impact and ability to comply with the MCL. Evaluation of the economic impact of an MCL includes the cost for removal of a contaminant from all size water systems, determination of the number of systems the MCL will affect, laboratory analytical fees, and the added cost to water customers.

Risk assessment and the eventual establishment of drinking water MCLs has been based on the assumption that adverse health effects are primarily the result of ingestion. Recent studies indicate that the use of water containing volatile contaminants, for purposes other than drinking, especially bathing, may also allow the contaminants to enter the body through inhalation and skin absorption. The Federal-State Toxicology and Risk Assessment Committee, a network of federal and state regulators and risk assessors concerned with drinking water issues, has concluded that exposure to VOCs through inhalation is on the average equivalent to exposure from ingestion, and that in the worst case dermal absorption of VOCs could be as much as 25 percent of the exposure from ingestion. Although these other routes of entry have not been specifically considered when establishing VOC MCLs, the current MCLs incorporate conservative uncertainty factors. Uncertainty factors include built-in measures to protect consumers from contaminant exposure from multiple routes of entry into their bodies. Uncertainty factors take into account intra and interspecies diversity and sensitivities, limited or incomplete data, significance of the adverse effect, length of exposure and pharmacokinetics (behavior of the chemical in the body).

Concentrations for VOC MCLGs and MCLs are reported in milligrams per liter (mg/L) or micrograms per liter (µg/L). One milligram per liter equals about one part per million (an example of one part per million is approximately one drop in 141 12-ounce sodas) and one microgram per liter equals about one part per billion (an example of one part per billion is approximately one drop in 141,000 12-ounce sodas).

Contaminants selected for MCL development, based on potential health risks and occurrence in drinking water, are divided into two major groups--carcinogens and noncarcinogens. Carcinogens are contaminants which may cause cancer, based on the findings of animal or human studies, and noncarcinogens are contaminants which may pose a health risk other than cancer. The MCLG/MCL development process differs for each group. The following is an explanation of each of these processes:

Determining an MCL for Noncarcinogens

For noncarcinogen MCL development, a reference dose (RfD) is calculated for each contaminant. The RfD is an estimate of the amount of a chemical that a person can be exposed to on a daily basis that is not anticipated to cause adverse health effects over the person's lifetime. The RfD is usually expressed in milligrams of chemical per kilogram of body weight per day (mg/kg/day).

The RfD is derived based on data primarily from scientific studies of animals subjected to varying doses of a particular chemical. This RfD is the amount of a chemical that has caused little or no adverse effects in an animal or human, divided by an uncertainty factor. The uncertainty factor can range from <u>one to 10,000</u>. The more uncertain scientists are about the contaminant concentration below which consumers will not experience an adverse health effect, the greater the uncertainty factor. For example, an uncertainty factor of 10 could be used in conjunction with a valid study of results from prolonged ingestion by humans, while an uncertainty factor of 1,000 could be used in conjunction with limited or incomplete results of experimental animal studies. EPA attempts to establish MCLs at a concentration that is conservative enough to protect all consumers, taking into consideration numerous uncertainties.

The MCL is then determined from the RfD by assuming that the protected individual weighs 70 kilograms (154 pounds), drinks 2 liters (approximately 2 quarts) of water per day and that as much as 80 percent of the daily intake of a chemical may come from other sources (e.g., air, food, etc.).

Determining an MCL for Carcinogens

EPA has developed the following five carcinogen classification groups:

Group A: Human Carcinogen

Sufficient evidence in human population studies to support causal association between exposure and cancer.

Group B: Probable Human Carcinogen

B1--Limited evidence in human population studies.
B2--Sufficient evidence from animal studies and inadequate or no evidence in humans.

Group C: Possible Human Carcinogen

Absence of data in humans. Limited evidence from animal studies.

Group D: Not Classified

Inadequate animal evidence.

Group E: No Evidence of Carcinogenicity for Humans

No evidence in multiple studies.

If toxicological evidence gathered during the risk assessment process leads to the classification of a contaminant as a human (Group A) or probable human (Group B) carcinogen, the MCLG is set at zero. The reason being that the MCLG is a health goal which is to pose little or no risk and it generally is agreed that there is no threshold for carcinogens, meaning that any exposure is assumed to represent some risk.

Estimates of carcinogenic risk associated with contaminated drinking water are based on a lifetime (70 years) consumption of two liters per day of water containing contaminants exhibiting carcinogenic potential. The risk is expressed as the number of cases of cancer in excess of those normally expected for a specified number of people (normal life-style accounts for about 25 percent of the population experiencing cancer during a lifetime) due to lifetime consumption of two liters of water per day containing a contaminant at a specified concentration. For example, in a case where water consumption has been estimated to represent a carcinogenic risk of one in one million you would expect to see one additional case of cancer per one million people in a lifetime or a total of 250,001 cases, compared to the currently expected 250,000 cases due to normal life-style.

Another way of expressing this same risk is to state that if there is a 25 percent chance of a person experiencing cancer due to normal life-style, then that same person drinking water containing a contaminant at the one in one million cancer risk level over a 70-year lifetime would increase the risk of cancer from 25 percent to 25.0001 percent.

Mathematical models are used to calculate drinking water concentrations associated with various excess lifetime cancer risk levels. The risk estimates are conservative, meaning that the actual risk experienced by a consumer will probably be less than the calculated risk. EPA attempts to establish MCLs for carcinogens at a concentration associated with excess lifetime cancer risks in the range of one in 10,000 to one in one million, while considering available analytical methods, treatment technology and economic and regulatory impact.

The carcinogenic potential of each of the VOCs in this guide can be found in Table 2 - VOC Summary. Cancer risks are listed for all VOCs classified as A, B1 or B2 carcinogens. The following discussion of risk is intended to provide consumers with a better understanding of risk as it relates to drinking water contamination.

Risk Associated with Drinking Water Contamination

Types of Risk

There are two types of risk—voluntary and involuntary. Cigarette smoking is an example of a voluntary risk which many individuals have chosen to take, knowing that this increases the risk of respiratory cancer. An example of an involuntary risk is consuming contaminated drinking water unknowingly, since drinking water is a basic need.

Risk of contaminant-induced disease has been defined by EPA as the "estimation of the association between the exposure to a substance and the incidence of some disease, based on scientific data." Quantitative risk is expressed as the number of incidences of a disease per total population exposed to the causative substance. For example, a risk of one in one million for a lifetime indicates that one person in every one million people exposed to the causative contaminant can be expected to experience a specified disease. To better visualize the relative size of one in one million, consider this ratio with regard to some commonly used quantity such as time. A one in one million time ratio is equivalent to one second in 11.6 days, one minute in 1.9 years or one day in 2,740 years.

In an attempt to place the risk associated with consuming contaminated water in the proper perspective, the following are examples of common situations that may increase the chance of death by one in one million.

Each year, about 400 children and adults in the U.S. are struck by lightning while working outside, at sports events, on the beach, mowing the lawn or during other outdoor activities. This risk is about 1.3 in a million per year.

The average American faces a one-in-a-million risk of death every six days from an ordinary fall and every 13 days from fire.

It is not possible to live in a world without risk, but it is the objective of regulatory agencies to maintain a proper balance between a controllable risk to which individuals are exposed and the benefits associated with the activity creating the risk.

Health Advisories

In addition to establishing MCLs to protect consumer health, EPA has developed guidance documents known as Health Advisories (HAs) for specific drinking water contaminants. HAs describe concentrations of contaminants in drinking water at which no adverse health effects can be expected by the consumer following one-day, 10-day, and lifetime (70 years) exposure. HA levels are not legally enforceable standards and do not consider any possible carcinogenic risk from lifetime exposure to these contaminants, but the advisories do discuss the carcinogenic potential of the contaminants. These guidance levels are used to determine the potability of water when a contaminant is detected but no MCL has been developed, and to determine if water containing a contaminant for which an MCL exists can be safely consumed for a limited period of time while the contamination problem is being corrected.

HA levels are derived in a manner similar to development of an MCL. The primary differences being that HA levels are entirely health-based, whereas MCL development also considers laboratory testing capability and effective processes to remove contaminants. The peer review process is much more extensive for development of an MCL.

Table 2 - VOC Summary included in this guide lists HA values. The one-day and 10-day HA values assume the protected individual is a 10-kilogram (22-pound) child consuming 1 liter (approximately 1 quart) of water per day, and the lifetime HA values assume the protected individual is a 70-kilogram (154-pound) adult consuming 2 liters of water per day. When calculating HA values, it is assumed that 100 percent of an individual's exposure to a contaminant comes from drinking water, except for lifetime values which are adjusted to account for other sources of exposure such as food or air.

Safety of Individual Water Supplies

Potential for VOC Contamination

Individual water supplies are not regulated by DEP or EPA. It is the responsibility of homeowners to monitor the quality of the water from their supply. The potential for VOCs in drinking water often depends on present and previous land use in the area around a water source. VOCs are used in all size businesses, found in most homes and are frequently transported from one location to another. Businesses such as dry cleaners, gas stations and industrial fabricators use VOCs to clean, degrease or complete other processes to produce their product. Accidental spillage of these chemicals and improper disposal techniques contribute to VOCs finding their way into drinking water. Abandoned lots or dumps on which debris is accumulating, landfills that were built prior to the use of liners and leachate treatment systems, and onlot septic systems also increase the potential for contamination of drinking water.

Testing Drinking Water for Contaminants

The best way to determine if VOCs are in drinking water is to have the water tested by a DEP-certified laboratory. Certification means that a particular laboratory has been evaluated by DEP and found to be qualified to collect, analyze and report results of water samples within quality control guidelines. Laboratories that are not certified may be less qualified and/or less objective in interpreting sample results and providing recommendations to address any detected contamination, especially if they will profit by sale of equipment or services to correct the contamination problem. Laboratories are certified for different types of contaminants (i.e., microbiological, inorganic, organic and radiological), so it is important to mention the type of contaminant the water is to be tested for when requesting information on a certified laboratory. The name and number of a local certified laboratory can be obtained from regional DEP offices or by visiting DEP's website at www.dep.state.pa.us (Keyword: "certified drinking water labs").

Private wells should be tested for bacteria at least once a year and for chemicals every three years.

Interpretation of Analytical Results

Table 2 - VOC Summary lists all the VOCs addressed in this guide. A Chemical Abstracts Service (CAS) number is provided with each chemical listing. Many chemicals have several different names by which they are identified, but each chemical has only one CAS number. The CAS number should always be used in conjunction with the chemical name to avoid any misunderstanding.

The results of drinking water analyses should be compared to the values on Table 2 - VOC Summary. It is very important to check the units in which results are reported. The units used in the table are mg/L (milligrams per liter). If results are reported in µg/L (micrograms per liter), they can be converted to mg/L by dividing by 1,000.

EXAMPLE: Result reported as 1.234 µg/L

$$\frac{1.234\ \mu g}{L} \times \frac{1\ mg}{1{,}000\ \mu g} = 0.001234\ mg/L$$

To convert mg/L to µg/L, multiply by 1,000.

Any analytical result at or below the MCLs listed on Table 2 - VOC Summary is considered by DEP and EPA to be a safe level for lifetime consumption. If levels are higher than the MCLs, corrective action may be needed.

Methods of Reducing Exposure to VOCs

Homeowners with a private, individual water system contaminated by VOCs have several options to correct the problem. A homeowner can secure a new source of water supply or treat the existing source to remove the VOCs.

A new source of water supply could include connecting to a public water system, extending the depth of an existing well, drilling a new well or purchasing DEP-permitted bottled water. In most cases, connecting to a public water system, if available, would probably be the best way to ensure that water meets current drinking water standards. Extending an existing well or drilling a new well will not guarantee that the new source of water supply will not contain the same contaminants as the existing source. Using bottled water will reduce risk due to ingestion, but will not address inhalation or dermal (skin) exposure.

The most common method used by homeowners to remove VOCs from drinking water is to install a point-of-use (POU) or point-of-entry (POE) water treatment device. A POU device treats only the water at a single tap (e.g., at the kitchen sink), while a POE device treats all the water entering the home. The advantage of a POE device is that inhalation and dermal exposure are addressed since it treats all the water entering the home. The disadvantage is that POE devices are more expensive. Home treatment devices are generally not required to protect public health when consumers are receiving water from a public water system that meets state and federal health standards.

POU and POE Treatment Devices for VOC Removal

Individual water system owners most commonly remove VOCs from drinking water with activated carbon filtration units. Activated carbon filters use carbon material made from coal, charcoal, wood or bone to remove VOCs from drinking water. The carbon contains a vast network of minuscule (very narrow) channels and a large amount of surface area for effective VOC removal. These activated carbon filters are designed to capture the VOC contaminants by attaching (adsorbing) them as the water passes through. Table 1 lists adsorbability of activated carbon for specific VOC compounds in drinking water. Of the 21 VOCs listed, only vinyl chloride is not efficiently removed by activated carbon. Aeration units in well ventilated areas work best for this contaminant.

The VOC removal efficiency of activated carbon filters depends on a number of factors including the length of time contaminated water is in contact with the activated carbon, the type of carbon used, and the extent of drinking water contamination. Before purchasing a unit, the volume of water which the unit is to treat daily and the quality of the water (i.e., specific contaminants and the concentration of these contaminants) to be treated should be determined. This information will be necessary in deciding which unit will do the best job of removing the contaminants of concern and last the longest without need for replacement.

TABLE 1

Removal of VOCs From Drinking Water By Activated Carbon Adsorption

The following VOC compounds are listed in decreasing order of activated carbon adsorbability. 1,2,4-Trichlorobenzene would probably be the most easily removed and vinyl chloride would probably be the most difficult to remove. The relative adsorbability may vary depending on contaminant concentrations and the number and type of contaminants in the water.

1.	1,2,4-Trichlorobenzene	12.	1,2-Dichloropropane
2.	1,4-Dichlorobenzene	13.	1,1,1-Trichloroethane
3.	1,2-Dichlorobenzene	14.	Benzene
4.	Styrene	15.	cis-1,2-Dichloroethylene
5.	Ethylbenzene	16.	1,1-Dichloroethylene
6.	Chlorobenzene	17.	1,2-Dichloroethane
7.	Carbon Tetrachloride	18.	trans-1,2-Dichloroethylene
8.	Toluene	19.	Chloroform
9.	Tetrachloroethylene	20.	Dichloromethane
10.	Trichloroethylene	21.	Vinyl Chloride
11.	1,1,2-Trichloroethane		

Additional Information on Home Treatment Devices

DEP also has published a *Citizen's Guide to Home Drinking Water Treatment Devices,* which is available from regional DEP offices or electronically on DEP's website at www.dep.state.pa.us (Keyword: "Drinking Water").

Neither EPA nor DEP certify, approve, or endorse POU/POE home treatment units. Since these devices are not certified by the government, anyone can manufacture and sell such devices. Occasionally a device may have a label that reads, "Registered with the EPA." This registration is required for devices that contain a chemical treatment that inhibits the growth of bacteria on the filter material. Registration means that the filter has been tested and found not to leach unacceptable levels of the bactericide. The registration process does *not* include an evaluation of VOC removal efficiency or the ability to kill harmful bacteria.

NSF International (NSF) is a private organization that tests and certifies treatment devices. An NSF seal on the unit certifies that it has met the national standards for design and performance. Units evaluated to determine their ability to remove VOCs from drinking water are listed under NSF Standard No. 53 Drinking Water Treatment Units--Health Effects, or Standard No. 58 Reverse Osmosis Drinking Water Treatment Systems. Those contaminants, which are effectively removed by the device, will be listed on the unit. An NSF listing of home treatment devices can be obtained by writing to:

NSF International
Dixboro Road
Ann Arbor, MI 48105
Telephone: 1-800-673-8010

or by visiting their website at http://www.nsfconsumer.org .

Temporary Solutions for VOC Removal

Boiling is another method that has been used by some homeowners to remove VOCs from drinking water. Although boiling is not the recommended method of home treatment, due to the possibility of inhaling vaporized VOCs, studies show that vigorously boiling water for 10 minutes will remove most of the VOCs. Water should be boiled vigorously for a full 10 minutes and be allowed to cool in a container open to the atmosphere. If this removal method is used, it is very important to ventilate the area in which the water is boiled to avoid inhalation of VOCs. In addition, the concentration of the other contaminants in the water that are not removed by boiling may increase. The increased concentration is due to the loss of water during boiling.

Use of unboiled water for bathing, washing clothes or dishes, flushing toilets, etc. poses a health risk due to inhalation or dermal exposure to VOCs. Since inhalation is a primary contributor to the total body intake of VOCs, second only to ingestion, it is important to ventilate the bathroom during and after bathing, and to ventilate the laundry room and kitchen when washing clothes and dishes.

TABLE 2
VOC SUMMARY

Chemical (CAS Number)	Standards (mg/L)		Health Advisories (mg/L)			Carcinogenic Potential	
			10-kg Child		70-kg Adult		
	MCLG	MCL	One Day (mg/L)	Ten Day (mg/L)	Lifetime	EPA Cancer Risk at 10^{-6}* (mg/L)	EPA Cancer Group
Benzene (71-43-2)	0	0.005	0.2	0.2	–	0.001	A
Carbon Tetrachloride (56-23-5)	0	0.005	4	0.2	–	0.0003	B2
Chlorobenzene (mono) (108-90-7)	0.1	0.1	4	4	0.1	–	D
o-Dichlorobenzene (95-50-1)	0.6	0.6	9	9	0.6	–	D
p-Dichlorobenzene (106-46-7)	0.075	0.075	11	11	0.075	–	C
1,2-Dichloroethane (107-06-2)	0	0.005	0.7	0.7	–	0.0004	B2
1,1-Dichloroethylene (75-35-4)	0.007	0.007	2	1	0.006	0.00006	C
cis-1,2-Dichloroethylene (156-59-2)	0.07	0.07	4	1	0.07	–	D
trans-1,2- Dichloroethylene (156-60-5)	0.1	0.1	20	1	0.1	–	D
Dichloromethane (75-09-2)	0	0.005	10	2	–	0.005	B2
1,2-Dichloropropane (78-87-5)	0	0.005	–	0.09	–	0.0006	B2
Ethylbenzene[a] (100-41-4)	0.7	0.7	30	3	0.7	–	D
Styrene[a] (100-42-5)	0.1	0.1	20	2	0.1	–	C
Tetrachloroethylene (127-18-4)	0	0.005	2	2	0.01	–	–
Toluene[a] (108-88-3)	1	1	20	2	1	–	D
1,2,4-Trichlorobenzene (120-82-1)	0.07	0.07	0.1	0.1	0.07	–	D
1,1,1-Trichloroethane (71-55-6)	0.2	0.2	100	40	0.2	–	D
1,1,2-Trichloroethane (79-00-5)	0.003	0.005	0.6	0.4	0.003	0.0006	C
Trichloroethylene (TCE) (79-01-6)	0	0.005	–	–	–	0.003	B2
Vinyl Chloride (75-01-4)	0	0.002	3	3	–	0.00002	A
Xylenes (Total) (1330-20-7)	10	10	40	40	10	–	D

Notes: CAS = **Chemical Abstracts Service**

[a] = **Dermal contact during bathing and showering may pose a significant risk at concentrations of concern via the ingestion route.**

* 10^{-6} = **One in one million**

Benzene

(CAS #71-43-2)

A. ***Synonyms***: Benzol 90, Pyrobenzol, Polystream, Coal naphtha, Phene

B. ***Properties***: Benzene is a clear, colorless, volatile, highly flammable liquid with a gasoline like odor. It is lighter than water and slightly soluble (1,800 mg/L) in water. Its taste threshold has been reported at 0.5 to 4.5 mg/L in drinking water.

C. ***Uses***: It is used as an intermediate (building block) for making a variety of organic compounds including rubber, plastics, styrene, detergents, pesticides, resins and synthetic fabrics like nylon and polyester. Other uses include: printing, lithography, paint thinners, dry cleaning and as an ingredient in gasoline.

D. ***Source of Exposure***: Benzene is released to air, land and water from industries that produce or use it. It is found in emissions from burning coal and oil, motor vehicle exhaust, evaporation from gasoline service stations and in industrial solvents. These sources contribute to elevated levels of it in the ambient air. The main exposure to benzene is through inhalation and skin contact. Tobacco smoke contains benzene and accounts for nearly half the national exposure to it. Benzene also has been found in fruits, fish, vegetables, nuts, dairy products, meat, poultry and eggs. Water and food contribute a small amount of benzene to the total daily intake in **non-smoking** adults (according to the International Programme on Chemical Safety 1993, it is between approximately 3 and 24 µg/kg of body weight per day).

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–high levels may cause central nervous system (CNS) effects and possibly death; at lower levels above the drinking water MCL, may cause central nervous system disturbances, immune system depression and bone marrow toxicity leading to aplastic anemia; and
2. Chronic Effects–may cause chromosomal aberrations in people who are chronically exposed at levels above the drinking water MCL, and blood cell production disorders. According to EPA, it has the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing benzene from drinking water.

Carbon Tetrachloride

(CAS #56-23-5)

A. ***Trade names and synonyms***: Methane tetrachloride; Tetrachloromethane; Perchloromethane

B. ***Properties***: Carbon tetrachloride is a colorless, volatile liquid with a sweet aromatic odor similar to chloroform. It is heavier than water and is slightly soluble (795 mg/L) in water. Its odor threshold has been reported at 0.52 mg/L in drinking water.

C. ***Uses***: It was used to make fluorocarbon propellants, fire extinguisher and refrigerants, though this has been declining steadily. Other uses have included: dry cleaning agent, solvent for oils, fats, lacquers, varnishes, rubber waxes, resins and as a grain fumigant. Consumer uses and grain fumigant are now banned and it is only used in some industrial applications.

D. ***Source of Exposure***: Carbon tetrachloride is released to air, land and water from industries that manufacture or use it, disposal in landfills where it may evaporate into the air or leach into groundwater, and from agricultural activities. It is also a common contaminant of indoor air; the sources of exposure appear to be building materials or products, such as cleaning agents, used in the home. Water and food are only minor sources.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause liver, lung and kidney damage at levels above the drinking water MCL for relatively short periods of time as well as possible central nervous system disturbances when inhaled; and
2. Chronic Effects–may cause liver and kidney damage from a lifetime exposure at levels above the drinking water MCL. According to EPA, there is some evidence that it has the potential to cause liver cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing carbon tetrachloride from drinking water.

Chlorobenzene

(CAS #108-90-7)

A. ***Synonyms***: Monochlorobenzene; Benzene chloride; Chlorobenzol; Phenyl chloride

B. ***Properties***: Chlorobenzene is a clear, colorless, volatile liquid with a faint, almond-like odor. It is heavier than water and is slightly soluble (450 mg/L) in water. Its taste/odor threshold has been reported at 0.050 mg/L in drinking water.

C. ***Uses***: It is used to produce other organic chemicals, dyestuffs and insecticides. It is also used as a solvent for adhesives, drugs, rubber, paints, dry cleaning, degreasing automobile parts and as a fiber-swelling agent in textile processing.

D. ***Sources of Exposure***: Chlorobenzene is released to air at and around sites producing and using it as a solvent in pesticide formulations, in producing other organic chemicals and dyestuffs, and as an industrial solvent. Human exposure occurs mainly in the workplace.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause anesthetic effects and impaired liver and kidney function from short-term exposures at levels above the drinking water MCL; and
2. Chronic Effects–may cause liver, kidney and central nervous system damage from long-term exposure at levels above the drinking water MCL. Headaches and irritation of the mucosa (mucus-secreting membranes) of the upper respiratory tract and eyes may occur when humans are chronically exposed by inhaling it. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing chlorobenzene from drinking water.

o-Dichlorobenzene

(CAS #95-50-1)

A. ***Synonyms***: 1,2-Dichlorobenzene; o-DCB

B. ***Properties***: o-Dichlorobenzene is a colorless, volatile liquid with a pleasant, aromatic benzene-like odor. It is heavier than water and slightly soluble (140 mg/L) in water. Its taste/odor threshold has been reported at 0.024 mg/L in drinking water.

C. ***Uses***: It is used as a chemical intermediate for making agricultural chemicals, primarily herbicides. Other present and past uses include: solvent for waxes, gums, resins, wood preservatives, paints; insecticide for termites and borers; in making dyes; as a coolant, deodorizer and degreaser.

D. ***Sources of Exposure***: 1,2-Dichlorobenzene is mostly released to air at and around manufacturing sites and facilities using it. Accidental spills and groundwater contamination at land disposal sites may account for o-dichlorobenzene contamination of drinking water.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause irritation to the eyes and respiratory tract, skin irritation and effects on the central nervous system when inhaled (EPA has no data on the acute toxicity as related to drinking water); and
2. Chronic Effects–may cause central nervous system, liver, kidney and blood cell damage from long-term exposure at levels above the drinking water MCL. If absorbed by the skin or inhaled, it may cause irritation to skin, eyes and respiratory system. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment:*** EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing o-dichlorobenzene from drinking water.

p-Dichlorobenzene

(CAS #106-46-7)

A. ***Synonyms***: 1,4-Dichlorobenzene; p-DCB

B. ***Properties***: p-Dichlorobenzene is a white, crystalline, noncorrosive, volatile and combustible solid with a penetrating mothball-like odor. It is heavier than water and slightly soluble (65.3 mg/L) in water. Its taste/odor threshold has been reported at 0.0045 mg/L in drinking water.

C. ***Uses***: It is used in moth control (moth balls and powder form) and as a deodorant for garbage and restrooms. It is also used as an insecticide and fungicide on crops, in producing other organic chemicals and in plastics, dyes and pharmaceuticals.

D. ***Sources of Exposure***: p-Dichlorobenzene is mostly released to air at and around sites directly producing and using it. In the home, breathing vapors from mothballs, diaper pail deodorizers and toilet bowl deodorizers can produce low-level exposure. Accidental spills and groundwater contamination at land disposal sites may account for p-dichlorobenzene contamination of drinking water.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause nausea, vomiting, headaches, and irritation of the eyes and respiratory tract; and
2. Chronic Effects–may cause anemia, skin lesions, appetite loss, yellow atrophy of the liver, adverse blood effects, respiratory and central nervous system disturbances from long-term exposure at levels above the drinking water MCL. According to EPA, there is some evidence that it has the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing p-dichlorobenzene from drinking water.

1,2-Dichloroethane

(CAS #107-06-2)

A. ***Synonyms***: Ethylene dichloride; EDC; 1,2-DCE

B. ***Properties***: 1,2-Dichloroethane is a colorless, oily, organic liquid with a sweet taste and chloroform-like odor. It is heavier than water and soluble (8,700 mg/L) in water. Its taste threshold in water has been reported at 29 mg/L in drinking water.

C. ***Uses***: It is used in making other chemicals including: vinyl chloride, tri- & tetra-chloroethylene, vinylidene chloride, trichloroethane, ethylene glycol, diaminoethylene, polyvinyl chloride, nylon, viscose rayon, styrene-butadiene rubber, in various plastics and as a lead scavenger in gasoline. It is also used as a solvent for resins and fats, degreasers, photography, photocopying, cosmetics, drugs, extraction of some spices and as a fumigant for grains and orchards.

D. ***Sources of Exposure***: 1,2-Dichloroethane is mostly released to air at and around sites producing and using it as well as its presence in gasoline. When used as a fumigant, treated agricultural products may contain small amounts of 1,2-dichloroethane. It has been detected in ground and surface community water supplies, with the highest concentrations being found near industrialized areas. For the majority of the U.S. population, the greatest source of exposure is from urban air, drinking water from contaminated aquifers and in the workplace.

E. ***Routes of Entry***:

   1. Oral–readily absorbed following ingestion;
   2. Inhalation–readily absorbed in the lungs; and
   3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

   1. Acute Effects–may cause central nervous system disturbances, adverse lung, kidney, liver, circulatory, gastrointestinal effects and eye irritation; and
   2. Chronic Effects–from EPA, no reliable data are available on chronic exposure at levels above the drinking water MCL; however, it has caused liver, kidney, immune system and central nervous system damage in **animals**. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing 1,2-dichloroethane from drinking water.

1,1-Dichloroethylene
(CAS #75-35-4)

A. ***Synonyms***: Vinylidene chloride; 1,1-DCE; 1,1-Dichloroethene

B. ***Properties***: 1,1-Dichloroethylene is a clear, colorless, volatile liquid with a mild, sweet, chloroform-like odor. It is heavier than water and slightly soluble (2,500 mg/L) in water. Its taste/odor threshold in water has been reported at 1.5 mg/L in drinking water.

C. ***Uses***: It is used in producing polyvinylidene chloride copolymers which in turn are used in the manufacture of food wrappings such as the Saran® types, nonflammable synthetic fibers and interior coatings for storage tanks and steel pipes.

D. ***Sources of Exposure***: 1,1-Dichloroethylene is mostly released as air emissions or in wastewater at and around industries producing and using it. A small percentage of the drinking water supplies may contain very low levels of 1,1-dichloroethylene. It has been detected in both raw and finished drinking water.

E. ***Routes of Entry***:

   1. Oral–readily absorbed following ingestion;
   2. Inhalation–readily absorbed in the lungs; and
   3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

   1. Acute Effects–may cause adverse central nervous system, respiratory system effects when inhaled, and adverse liver effects due to acute exposures at levels above the drinking water MCL; and
   2. Chronic Effects–may cause liver and kidney damage, as well as toxicity to the developing fetus at levels above the drinking water MCL. Its vapor is irritating to eyes, nose and throat. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing 1,1-dichloroethylene from drinking water.

cis-1,2-Dichloroethylene
(CAS #156-59-2)

A. ***Synonyms***: cis-1,2-DCE; 1,2-Dichloroethene; 1,2-DCE

B. ***Properties***: cis-1,2-Dichloroethylene is a clear, colorless, flammable, volatile liquid with a pleasant odor. It is heavier than water and is soluble (3,500 mg/L) in water. Its taste/odor threshold has not been reported in drinking water.

C. ***Uses***: It is used - usually as a mixture with its trans form - as a chemical intermediate in producing chlorinated compounds. It is also used as a solvent for waxes, resins and acetylcellulose, to extract rubber, phenol and camphor as well as oils and fats from fish and meat, in making pharmaceuticals and artificial pearls, for retarding fermentation and as a coolant in refrigeration plants.

D. ***Sources of Exposure***: cis-1,2-dichloroethylene is mostly released to air at and around industries producing and using it. Workplace exposure to this compound may include inhalation or skin contact. Another source of exposure to it is from contaminated drinking water. It has been detected in both raw and finished drinking water, principally from groundwater sources.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause central nervous system disturbances (nausea, drowsiness and feeling tired) at levels above the drinking water MCL; and
2. Chronic Effects–may cause liver, circulatory and nervous system damage from long-term exposure at levels above the MCL, and skin, eye and respiratory irritations from exposure to its vapor. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing cis-1,2-dichloroethylene from drinking water.

trans-1,2-Dichloroethylene
(CAS #156-60-5)

A. ***Synonyms***: 1,2-Dichloroethene, trans-1,2-DCE, 1,2-DCE

B. ***Properties***: trans-1,2-Dichloroethylene is a colorless, flammable, volatile liquid with a pleasant odor. It is heavier than water and is soluble (6,300 mg/L) in water. Its taste/odor threshold has been reported at 0.0043 mg/L in drinking water.

C. ***Uses***: It is used - usually as a mixture with its cis form - mostly as a chemical intermediate in the production of chlorinated compounds. It is also used as a general solvent for organic material, in dye extraction, rubber extraction, perfume manufacturing, in lacquers and medicine, as a refrigerant and to decaffeinate coffee.

D. ***Sources of Exposure***: trans-1,2-dichloroethylene is mostly released to air at and around sites producing and using it. Workplace exposure to this compound also may include inhalation or skin contact. Another source of exposure to it is from contaminated drinking water. It has been detected in both raw and finished drinking water, principally from groundwater sources.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause central nervous system disturbances from short-term exposures above the drinking water MCL; and
2. Chronic Effects–may cause liver, nervous system and circulatory system damage at levels above the drinking water MCL, and skin, eye and respiratory irritations from exposure to its vapor. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing trans-1,2-dichloroethylene.

Dichloromethane
(CAS #75-09-2)

A. ***Synonyms***: Methylene chloride; Methylene dichloride; Methylene bichloride; DCM

B. ***Properties***: Methylene chloride is a colorless, volatile liquid with a mild, sweet odor. It is heavier than water and soluble (20,000 mg/L) in water. Its taste/odor threshold has been reported at 9.1 mg/L in drinking water.

C. ***Uses***: It is used in producing paint and varnish removers, as solvent and cleaning agent in various industries, aerosol products, metal cleaning products, in extraction of caffeine, cocoa, fats, spices and beer hops, and in insecticides and fumigants.

D. ***Sources of Exposure***: Dichloromethane is mostly released to air at and around sites producing and using it. Air exposure most often occurs in the workplace or from living near a chemical plant manufacturing or using it. Exposure to smaller amounts may occur through food and drinking water. In food, the highest concentrations have been found in spices (i.e., cassia, allspice and nutmeg). Additional exposure may occur through the use of paint removers or aerosols.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause central nervous system disturbances, blood cell damage and circulatory system damage from acute exposures above the drinking water MCL; and
2. Chronic Effects–may cause liver damage and nervous system damage from long-term exposures at levels above the drinking water MCL. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon in combination with packed tower aeration as the best available treatment technology for removing dichloromethane from drinking water.

1,2-Dichloropropane
(CAS #78-87-5)

A. ***Synonyms***: Propylene dichloride; 1,2-DCP

B. ***Properties***: 1,2-Dichloropropane is a colorless liquid with a chloroform-like odor. It is heavier than water and soluble (2,700 mg/L) in water. Its taste/odor threshold has been reported at 0.01 mg/L in drinking water.

C. ***Uses***: It is used in making tetrachloride and perchloroethylene (other organic chemicals). It is also used in making lead-free gasoline, paper coating, as a solvent in degreasing operations, soil fumigant for nematodes and insecticide for stored grain.

D. ***Sources of Exposure***: 1,2-Dichloropropane is mostly released into the air or in wastewater during its production or use as an intermediate in producing other organic chemicals. There have been significant releases during its former use as a soil fumigant. Another form of release may occur as leachate from municipal landfills. It has been found in both surface and groundwater.

E. ***Routes of Entry***:

1. Oral–absorbed from the gastrointestinal tract;
2. Inhalation–absorbed; and
3. Dermal–absorbed, but not as rapidly as through the other routes.

F. ***Some Health Effects***:

1. Acute Effects–may impair the functions of the liver, kidneys, adrenal glands, bladder, and the gastrointestinal and respiratory tracts from short-term exposures above the drinking water MCL; and
2. Chronic Effects–may affect the liver, kidneys, bladder, gastrointestinal tract and the respiratory tract from long-term exposures above the drinking water MCL. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing 1,2-dichloropropane from drinking water.

Ethylbenzene
(CAS #100-41-4)

A. ***Synonyms***: Ethyl benzol; Phenyl ethane

B. ***Properties***: Ethylbenzene is a clear, colorless liquid with a sweet, gasoline-like odor. It is lighter than water and has low solubility in water (140 mg/L). Its taste/odor threshold has been reported at or above 0.029 mg/L in drinking water.

C. ***Uses***: It is used mostly in making styrene, as a solvent for coatings, as an ingredient in asphalt and naphtha, in automobile and aviation fuels, and in producing synthetic rubber and cellulose acetate.

D. ***Sources of Exposure***: Ethylbenzene mostly enters the air from fugitive emissions and exhaust connected with its use in gasoline. It may also be released into the air, wastewater or as spills during its production or use. Low levels have been found in groundwater supplies, but exposure occurs mainly by inhalation.

E. ***Routes of Entry***:

1. Oral–readily absorbed from the gastrointestinal tract in test animals;
2. Inhalation–64 percent of dose absorbed by human volunteers; and
3. Dermal–118 micrograms per cm^2 per hour absorbed through skin in humans.

F. ***Some Health Effects***:

1. Acute Effects–may cause sleepiness, fatigue, headaches, and mild eye and respiratory irritation in humans from short-term exposures at levels above the drinking water MCL or from acute inhalation exposure; and
2. Chronic Effects–may have effects on the blood, liver, kidneys, central nervous system and eyes from long-term exposure at levels above the drinking water MCL. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing ethylbenzene from drinking water.

Styrene
(CAS #100-42-5)

A. ***Synonyms***: Ethenylbenzene; Styrol; Cinnamol

B. ***Properties***: Styrene is a colorless, oily liquid with a characteristic sweet and pleasant odor. It is lighter than water and slightly soluble (310 mg/L) in water. Its taste/odor threshold in water has been reported at 0.73 mg/L in drinking water.

C. ***Uses***: It is used mostly in producing polystyrene plastics and resins, coatings and paints. Styrene is also used as an intermediate in producing other materials, such as ion exchange resins and copolymers.

D. ***Sources of Exposure***: Styrene has been detected in ambient (outside surrounding air) air during its production and its use in polymer manufacture. Consumers may be exposed to styrene through contact with resin products used in fiberglass boat construction and repair, and in auto body fillers. Indoor air is the principal route of styrene exposure for the general population, usually as emissions from building materials, consumer products and tobacco smoke. Low-level contamination of food and drinking water may occur.

E. ***Routes of Entry***:

1. Oral–rapid and virtually complete absorption;
2. Inhalation–human studies have shown approximately 2/3 of the administered concentration is retained and absorbed by the lungs; and
3. Dermal–absorbed through the skin.

F. ***Some Health Effects***:

1. Acute Effects–may cause central nervous system effects such as depression, loss of concentration, weakness, fatigue and nausea, and possibly eye, nose and throat irritation from acute exposures at levels above the

drinking water MCL. Acute inhalation exposure may cause respiratory effects, such as mucous membrane irritation, eye irritation and gastrointestinal effects; and

2. Chronic Effects–may cause nerve tissue and liver damage from long-term exposures at levels above the drinking water MCL. Long-term inhalation exposure may cause nervous system effects and minor effects on some kidney enzyme functions and on the blood. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing styrene from drinking water.

Tetrachloroethylene

(CAS #127-18-4)

A. ***Synonyms***: PCE; Perchloroethylene; 1,1,2,2-Tetrachloroethylene, Perc; Tetrachloroethene

B. ***Properties***: Tetrachloroethylene is a colorless, volatile liquid with a chloroform-like odor. It is heavier than water, and slightly soluble (150 mg/L) in water. Its taste in water has been reported at or above 0.3 mg/L in drinking water.

C. ***Uses***: It is used in the textile industry for processing, finishing, sizing and as a component of aerosol dry cleaning products. Other uses include: an intermediate in the making of fluorocarbons, an insulating/cooling fluid in electric transformers, a metal degreaser, in typewriter correction fluids, as veterinary medication against worms, once used as grain protectant/fumigant.

D. ***Sources of Exposure***: Tetrachloroethylene has been detected in air in and around dry cleaning establishments, metal cleaning operations, some chemical plants, wastewater from manufacturing facilities such as metal finishing, aluminum forming organic chemical/plastic manufacturing and municipal treatment plants. High levels in drinking water are usually the result of spills or improper waste disposal. Water pollution can occur from tetrachloroethylene leaching from vinyl liners in asbestos-cement water pipelines for water distribution, and during chlorination water treatment, where it can be formed in small quantities.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause central nervous system disturbances, skin and eye irritation, and possible kidney and liver damage from acute exposures at levels above the drinking water MCL; and
2. Chronic Effects–may have detrimental effects on the central nervous system, liver and kidneys from long-term exposures at levels above the drinking water MCL. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing tetrachloroethylene from drinking water.

Toluene

(CAS #108-88-3)

A. ***Synonyms***: Methylbenzene; toluol

B. ***Properties***: Toluene is a clear, colorless liquid with a sweet, pungent odor. It is lighter than water and slightly soluble in water (535 mg/L). Its taste has been reported as 1 mg/L and odor has been reported at 0.04 mg/L in drinking water.

C. ***Uses***: It is used as a blending agent in the production of gasoline to improve its octane rating. It also is used as a starting material in producing benzene and other organic solvents, as a solvent for paints, coatings, gums, oils and resins, in cements, antifreezes, detergent production, in cosmetics and some inks.

D. ***Sources of Exposure***: Toluene is released into the air mostly from the evaporation of petroleum fuels, toluene-based solvents and thinners, and motor vehicle exhaust. A major source of exposure is in indoor air from the use of common household products (paints, paint thinners, adhesives and nail polish) and cigarette smoke. It also is released into waterways or spills on land during storage, transport and disposal of fuels and oils; from its production and use in preparing other products. It is found at low levels in food and drinking water.

E. ***Routes of Entry***:

1. Oral–relatively rapid absorption by the gastrointestinal tract in test animals;
2. Inhalation–rapid absorption by lungs in humans; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–low oral toxicity to central nervous system and may cause fatigue, headache, nausea, weakness, confusion and lack of coordination from acute exposures at levels above the drinking water MCL; and
2. Chronic Effects–in humans, central nervous system and peripheral nervous system effects such as spasms, tremors, imbalance; impairment of memory, speech, vision, hearing and coordination; as well as liver and kidney damage from long-term exposures at levels above the drinking water MCL. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing toluene from drinking water.

1,2,4-Trichlorobenzene
(CAS #120-82-1)

A. ***Synonyms***: TCB; asym-Trichlorobenzene; Hostetex L-Pec

B. ***Properties***: 1,2,4-Trichlorobenzene is a colorless, aromatic, volatile liquid. It is heavier than water and slightly soluble (30 mg/L) in water. Its odor threshold has been reported as 3 mg/L in drinking water.

C. ***Uses***: It is used as a dye carrier and an herbicide intermediate. It also is used as a heat-transfer medium, dielectric fluid, degreaser and solvent, wood preservative and in abrasive formulations. It was once used as a soil treatment for termite control.

D. ***Sources of Exposure***: 1,2,4-Trichlorobenzene is released into the air mostly during its manufacture and use. Work place inhalation exposure is the most frequent source of contact. It generally gets into drinking water by discharges from industrial activities.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed through the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause changes to the liver, kidneys and adrenal glands from acute exposures at levels above the drinking water MCL; and
2. Chronic Effects–may cause changes to the adrenal glands from long-term exposures at levels above the drinking water MCL. According to EPA, there is presently no evidence that it has the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing 1,2,4-trichlorobenzene from drinking water.

1,1,1-Trichloroethane
(CAS #71-55-6)

A. ***Synonyms***: 1,1,1-TCA; Methyl chloroform; Triethane

B. ***Properties***: 1,1,1-Trichloroethane is a colorless, volatile liquid with a sweet, chloroform-like odor. It is heavier than water and soluble (4,400 mg/L) in water. Its taste/odor threshold has been reported at 0.97 mg/L in drinking water.

C. ***Uses***: It is used in vapor degreasing of metal products. It is also used in inks, metal-cutting oils, textile processing and dyeing, glue, typewriter correction fluid, as an intermediate in producing organic chemicals and as a vapor depressant in aerosols. Agricultural uses have included post-harvest fumigation of strawberries; for degreening citrus fruits; as a solvent for various insecticides.

D. ***Sources of Exposure***: 1,1,1-trichloroethane is released mostly from air emissions during its production or use as metal degreasing agents, paints, glues and cleaning products. Other exposure may be due to its common use in home and office products. In drinking water, most exposure can be attributed to groundwater contamination from improper waste disposal activities.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause damage to the liver, central nervous system and circulatory system from acute exposures at levels above the drinking water MCL; and
2. Chronic Effects–may cause liver, nervous system and circulatory system damage from a lifetime exposure at levels above the drinking water MCL. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment:*** EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing 1,1,1-trichloroethane from drinking water.

1,1,2-Trichloroethane

(CAS #79-00-5)

A. ***Synonyms***: Vinyl trichloride; B-trichloroethane; Ethane trichloride; 1,1,2-TCE

B. ***Properties***: 1,1,2-Trichloroethane is a colorless liquid with a pleasant, chloroform-like odor. It is heavier than water and soluble (4,400 mg/L) in water. Its taste/odor threshold has not been reported in drinking water.

C. ***Uses***: It is used in producing 1,1-dichloroethylene (vinylidene chloride) and tetrachloroethanes, as a solvent for chlorinated rubber, fats, oils, waxes and resins, in producing Teflon® tubing and in making lacquers and coatings.

D. ***Source of Exposure***: 1,1,2-Trichloroethane is released in the work place where it is used in producing vinylidene chloride or used as a solvent. Low levels have been detected in air in the vicinity of industrial sources. Exposure from contaminated drinking water appears to be rare. Some discharges occur in wastewater, in leachates and volatile emissions from landfills.

E. ***Routes of Entry***:

1. Oral–extensively absorbed following ingestion by test animals;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–readily absorbed through the skin of test animals.

F. ***Some Health Effects***:

1. Acute Effects–may cause irritation of gastrointestinal tract; red or hemorrhaged lungs; pale liver from acute exposures at levels above the drinking water MCL; and
2. Chronic Effects–may cause damage to liver and kidneys from long-term exposures at levels above the drinking water MCL. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing 1,1,2-trichloroethane from drinking water.

Trichloroethylene

(CAS #79-01-6)

A. ***Synonyms***: TCE; Trichloroethene; Acetylene trichloride; Tri; Trilene

B. ***Properties***: Trichloroethylene is a clear, colorless or blue mobile, volatile liquid with a sweet, chloroform-like odor. It is heavier than water and slightly soluble (1,000 mg/L) in water. Its taste/odor threshold has been reported at 0.31 mg/L in drinking water.

C. ***Use***: It is used as a metal degreasing agent, in the textile industry for finishing operations, as an intermediate in producing organic chemicals and pharmaceuticals, solvents for dry cleaning, extraction as a refrigerant/heat exchange liquid, an insulating/cooling fluid in electric transformers, in typewriter correction fluids, as veterinary medication against worms, and was once used as grain protectant/fumigant.

D. ***Sources of Exposure***: Trichloroethylene is mostly released as air emissions from metal degreasing plants. Wastewater from metal finishing, paint and ink formulation, electrical/electronic components and rubber processing industries also may contain trichloroethylene. Most of the trichloroethylene found in drinking water can be attributed to groundwater contamination from improper waste disposal activities.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause vomiting and abdominal pain from acute exposures at levels above the drinking water MCL; and
2. Chronic Effects–may cause liver damage from a lifetime exposure at levels above the drinking water MCL. Effects on the kidneys, immune and endocrine systems have also been seen in humans exposed to trichloroethylene in the work place or from contaminated drinking water. According to EPA, there is some evidence that it may have the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing trichloroethylene from drinking water.

Vinyl Chloride

(CAS #75-01-4)

A. ***Synonyms***: Monochloroethylene; Chloroethene

B. ***Properties***: Vinyl chloride is a colorless gas with a sweet odor. It is lighter than water and slightly soluble (2,700 mg/L) in water. Its taste/odor threshold has been reported at 3.4 mg/L in drinking water.

C. ***Uses***: It is used in manufacturing numerous products including polyvinyl chloride (PVC) resins for the building and construction industries, 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.

D. ***Sources of Exposure***: Vinyl chloride is mostly released as air emissions from production and manufacturing facilities. Wastewater from these processing industries also may contain vinyl chloride. Most human exposure will occur from inhaling air emissions in industrial facilities and from ingesting contaminated food and drinking water which has come into contact with polyvinyl chloride packaging material or pipe which has not been treated adequately to remove residual vinyl chloride. Vinyl chloride may also be produced when chlorinated solvents break down in groundwater and landfills.

E. ***Routes of Entry***:

1. Oral–readily absorbed following ingestion;
2. Inhalation–readily absorbed in the lungs; and
3. Dermal–absorbed through the skin, but not as readily as through other routes of exposure.

F. ***Some Health Effects***:

1. Acute Effects–may cause central nervous system disturbances from acute exposures above the drinking water MCL, and slight skin and eye irritation after inhalation; and
2. Chronic Effects–may cause liver changes and nerve damage at levels above the drinking water MCL and to workers exposed to vinyl chloride by inhalation. A small percentage of individuals whose occupations have exposed them to high levels of vinyl chloride in air have developed "vinyl chloride disease" which affects their fingers (when exposed to

the cold), changes in the bones in the fingertips, joint and muscle pain, and changes to the skin. According to EPA, it has the potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon in combination with packed tower aeration as the best available treatment technology for removing vinyl chloride from drinking water.

Xylenes

(Mixture of Ortho, Meta and Para Isomers)
(CAS #1330-20-7)

A. ***Synonyms***: Dimethylbenzene; Xylol

B. ***Properties***: Xylenes are colorless, volatile liquids with a sweet odor. The commercial product "mixed xylenes" generally contains approximately 40 percent meta-xylene and 20 percent each of ortho-xylene, para-xylene, and ethylbenzene, as well as small quantities of toluene. This mixture is lighter than water and slightly soluble (130 mg/L) in water. Its odor threshold has been reported as 0.00005 mg/L in air.

C. ***Uses***: It is used in a broad spectrum of applications, mostly as a solvent for which its use is increasing as a safe replacement for benzene. Xylenes are also frequently used as solvents, along with other solvents such as toluene and benzene, in the rubber industry, for alkyl resins, lacquers, enamels, rubber cement and pesticide sprays. The individual forms of xylene are extensively used in making synthetic agents. Also they are used in producing plasticizers and components of polyester fiber, film and fabricated items. Xylenes are a natural component of aviation and automobile gasoline.

D. ***Sources of Exposure***: Xylenes are mostly released as emissions from petroleum refining, gasoline and diesel engines; emissions from its use as a solvent and in organic synthesis; leaks and evaporation losses during transportation and storage of gasoline and other fuels and from carburetor losses; agricultural spraying. Xylenes are naturally produced by many plants, and are a component of petroleum and coal tar. Low levels occur in drinking water, food and air.

E. ***Routes of Entry***:
   1. Oral–absorbed in test animals;
   2. Inhalation–absorbed; and
   3. Dermal–absorbed.

F. ***Some Health Effects***:
   1. Acute Effects–may cause disturbances in the central nervous system, such as changes in cognitive abilities, balance and coordination from acute exposures at levels above the drinking water MCL; and
   2. Chronic Effects–may cause damage to the central nervous system, liver and kidneys from long-term exposures at levels above the drinking water MCL. According to EPA, there is inadequate evidence to determine its potential to cause cancer from a lifetime exposure at levels above the drinking water MCL.

G. ***Water Treatment***: EPA has identified granular activated carbon adsorption and packed tower aeration as the best available treatment technologies for removing xylenes from drinking water.

Glossary

Carcinogenic

Any substance that can cause or contribute to the production of cancer.

Degradation

A type of organic chemical reaction in which a compound is converted into a simpler compound in stages.

Epidemiological study

Study of human populations to identify causes of disease. Such studies often compare the health status of a group of persons who have been exposed to a suspect agent with that of a comparable non-exposed group.

Fugitive Emissions

Air pollutants released to the air other than those from stacks or vents; typically small releases from leaks in plant equipment such as valves, pump seals, flanges, sampling connections, etc. Other examples include pollutants that may escape through doors, windows, etc.

Ingestion

Type of exposure through the mouth.

Inhalation

The drawing of air or other substances into the lungs.

Interspecies

An uncertainty factor that is applied to account for the extrapolation of laboratory animal data to humans.

Intraspecies

The intraspecies UF is applied to account for variations in susceptibility within the human population and the possibility (given a lack of relevant data) that the database available is not representative of the dose/exposure-response relationship in the most susceptible subpopulations among the human population.

Leachate

Any liquid, including any suspended components in the liquid, that has percolated through or drained from waste.

Mucous membrane

The moist tissue that lines some organs and body cavities (such as nose, mouth, lungs) and secretes mucous (a thick fluid).

Odor Threshold

The lowest concentration of a substance in air that can be smelled. Odor thresholds are highly variable because of the differing ability of individuals to detect odors.

Organic

In chemistry, any compound containing carbon.

Potable water

Water that is safe and satisfactory for drinking and cooking.

Solubility

The ability of a substance to form a solution with another substance.

Surveillance

Continual or frequent monitoring and verification of the status of an entity and the analysis of records to ensure that specified requirements are being fulfilled.

Taste Threshold

The minimum concentration at which taste sensitivity to a particular substance or food can be perceived.

Threshold

The lowest dose of a chemical at which a specified measurable effect is observed and below which it is not observed.

Units of measurement - concentration of contaminants in water

1 milligram per liter (mg/L) is equal to 1 part per million (ppm).

Volatility

The property of a substance or substances to convert into vapor or gas without chemical change.

Additional Information on VOCs

This guide provides some basic information on VOCs in drinking water. More detailed information can be obtained from the organizations that have been discussed or publications that have been listed in this guide. The following are additional sources of VOC information:

- Public water system serving your home;
- EPA Region III in Philadelphia, (215) 814-2300; or visit their website at www.epa.gov/region03
- EPA Office of Ground Water and Drinking Water in Washington, D.C., (202) 260-5543; or visit their website at www.epa.gov/safewater
- EPA Safe Drinking Water Hotline, (800) 426-4791
- Regional DEP offices

Southeast Region	
Main Telephone:	484-250-5900
24-Hour Emergency:	484-250-5900
Southwest Region	
Main Telephone:	412-442-4000
24-Hour Emergency:	412-442-4000
Southcentral Region	
Main Telephone:	717-705-4700
24-Hour Emergency:	1-877-333-1940
Northwest Region	
Main Telephone:	814-332-6945
24-Hour Emergency:	1-800-373-3398
Northeast Region	
Main Telephone:	570-826-2511
24-Hour Emergency:	570-826-2511
Northcentral	
Main Telephone:	570-327-3636
24-Hour Emergency:	570-327-3636

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Federal Register. National Primary Drinking Water Regulations; Synthetic Organic Chemicals and Inorganic Chemicals; Final Rule. Vol. 56, No. 20, January 30, 1991.

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http://www.epa.gov/ost/drinking/standards/dwstandards.pdf

Agency for Toxic Substances and Disease Registry, Division of Toxicology
http://www.atsdr.cdc.gov/toxfaq.html

Definition of Inhalation; Dorland's Illustrated Medical Dictionary
http://www.mercksource.com/pp/us/cns/cns_health_library_frame.jsp?pg=/pp/us/cns/cns_hl_dorlands.jsp?pg=/pp/us/common/dorlands/dorland/dmd_a-b_00.htm&cd=3d

Definition of taste threshold, Dept. of Medical Oncology, University of Newcastle upon Tyne, NE1 7RU, United Kingdom
http://cancerweb.ncl.ac.uk/omd/contents/T.html

Drinking Water Contaminants, National Primary Drinking Water Regulations Contaminant Specific Fact Sheets Volatile Organic Chemicals - Technical and Consumer Versions
http://www.epa.gov/safewater/

Drinking Water Contamination: Understanding the Risks, University of Maine, Cooperative Extension
http://www.umaine.edu/waterquality/publications/7023.htm

Hazardous Substances Data Bank
http://toxnet.nlm.nih.gov/

Health Effects Notebook for Hazardous Air Pollutants
http://www.epa.gov/ttnatw01/hlthef/hapindex.html

International Chemical Safety Cards (ICSCS)
http://www.cdc.gov/niosh/ipcs/icstart.html

Lightning Safety Outdoors, National Weather Service Office of Climate, Weather, and Water Services
http://weather.gov/om/wcm/lightning/outdoors.htm

Solubility Table, Chapter 250. Administration of Land Recycling Program, Demonstration of Attainment … 250.701, APPENDIX A Table 5—Physical and Toxicological Properties A. Organic Regulated Substances
http://www.pacode.com/secure/data/025/chapter250/s250.708.html

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http://sd.water.usgs.gov/nawqa/pubs/wrir/wrir02_4085.pdf

Term List, U.S. EPA
http://oaspub.epa.gov/trs/trs_proc_qry.alphabet?p_term_nm=A

The 10th Report on Carcinogens
http://ehp.niehs.nih.gov/

Understanding Units of Measurement, U.S. EPA, Region 7, Information for Citizens
http://www.epa.gov/region07/citizens/amoco/units_measurement.htm

NOTES

Bureau of Water Standards and Facility Regulation
P.O. Box 8467
Harrisburg, PA 17105-8467

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