air ALLIANCE HOUSTON

Air Pollution Fact Sheets

What you need to know about Houston's most hazardous air pollutants

Glossary of terms, abbreviations and acronyms

EPA – U.S. Environmental Protection Agency

DHHS – Department of Health and Human Services

IARC – International Agency for Research on Cancer

NEI – National Emissions Inventory

NOx – Nitrogen Oxides

VOC – Volatile organic compounds are highly reactive carbon compounds that may be harmful by themselves or once emitted and can react with other gases in the air to create toxic compounds. They have a high vapor pressure and low water solubility.

Carcinogen – a substance capable of causing cancer in living tissue.

Cardiovascular system – This system consists of the heart, blood vessels, and blood and ensures that your body gets the oxygen, nutrients and other things it needs while getting rid of things it doesn't.

Gastrointestinal system – This system includes the mouth, pharynx (throat), esophagus, stomach, intestines and liver. The primary function is to absorb nutrients and remove waste.

Genotoxicity – a chemical or agent that can cause DNA or chromosomal damage.

Immune system – Made up of bone marrow, the thymus, lymph nodes, spleen and skin. The primary function is to protect the body from germs and toxins. The outer response can include mucus and tear production, coughing and more; the inner response can include antibodies and fevers etc..

Integumentary system – The network of organs forming a physical barrier to the external environment including the skin, hair, nails, and associated glands. This system is a large part of the outer response of the immune system.

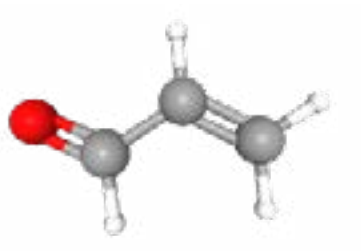
Lymphatic system – A part of the body's immune system. Lymph fluid passes through lymph nodes. A network of lymph vessels connects the lymph nodes together. You have nodes throughout your body.

Nervous system – This system consists of your brain, spinal cord and the nerves that go throughout the body. These organs and nerves handle functions from breathing to throwing a ball. Respiratory system – This system includes your airways, lungs and blood vessels. Because the lungs are connected to your blood vessels, air pollutants such as those listed can severely affect your health.

Acrolein

What is it?

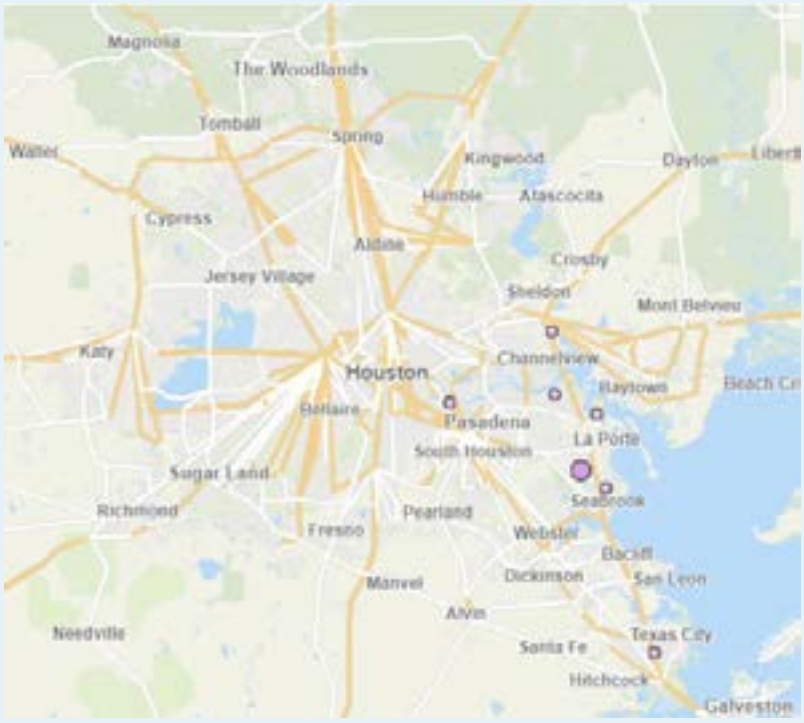
Acrolein [*ah*-**krol**-lee-in] is a clear or yellow liquid with a burnt, sweet, pungent odor. It is primarily used to make other chemicals and can also be found in animal feed supplements.[1,2] Acrolein may also be used as a pesticide and is occasionally added into the irrigation and the water supplies of some industrial plants to control underwater plant, algae, and slime growth. At much higher concentrations, it is used as a chemical weapon component.[1] However, since acrolein degrades quickly in air, water, and soil, environmental accumulation is rare.[2]



Emission sources

In industrial chemistry, acrolein is produced by the oxidation of propylene, which is derived from the steam cracking of propane from fossil fuel feedstocks.

Acrolein is primarily released by industrial sources, such as waste incinerators, furnaces, power plants, and the combustion of petrochemical fuels and certain plastics.[1,3] Acrolein also enters the environment from human processes like gas and diesel motor vehicle emissions, burning tobacco, overheating cooking oils, and burning organic matter. Acrolein is also formed through the reactions and breakdown of other airborne pollutants, such as 1,3-Butadiene.[3]



Map of acrolein emitting TRI facilities in Houston (2020)

According to the U.S. Environmental Protection Agency's (EPA) National Emissions Inventory (NEI), the Houston area emitted approximately 100,000 pounds of acrolein in 2017. Of these emissions, approximately 88% were attributed to mobile sources (such as automobile traffic), 4% to industrial sources, 4% to fuel combustion sources, and 4% to fires.[4]

1 Agency for Toxic Substances and Disease Registry. 2007. "Toxicological Profile for Acrolein." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp124.pdf.

2 Faroon, O., N. Roney, J. Taylor, A. Ashizawa, M. H. Lumpkin, and D. J. Plewak. "Acrolein health effects." Toxicology and industrial health 24, no. 7 (2008): 447-490.

3 Gomes, R., M. E. Meek, and the World Health Organization. Acrolein. World Health Organization, 2002.

4 Environmental Protection Agency. 2017. "2017 National Emissions Inventory (NEI) Data." United States Environmental Protection Agency. https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data.

Health effects

Acrolein can cause toxic effects through inhalation, oral, and dermal exposures. Acrolein primarily enters the body through inhalation, where it can enter the body's tissues within seconds. It's currently unknown if eating food or drinking water containing acrolein will affect your health, but animal studies show that oral exposure to acrolein can lead to stomach irritation, vomiting, stomach ulcers, and bleeding.[1]

RESPIRATORY SYSTEM:

- When inhaled, acrolein can cause irritation of the nose, throat, and lungs, accompanied by congestion and a decrease in breathing rate.
- More serious health problems can occur with higher amounts of acrolein in the air, including lung hemorrhage and death.[2] [3]

INTEGUMENTARY SYSTEM:

Contact with acrolein vapor or liquid causes severe skin and eye irritation.

- At low airborne levels, eye irritation and increased blinking occurs. At these low levels, humans seem to adapt to acrolein-caused eye irritation.
- At high levels, humans will experience increased eye irritation and tear production. It is unknown at what level acrolein liquid or vapor will cause structural damage to the eye.[1]

IS THIS A CARCINOGEN?

There is little evidence proving if acrolein is a carcinogen. The International Agency for Research on Cancer (IARC) has not classified acrolein according to its carcinogenicity and the EPA has stated that the potential carcinogenicity of acrolein cannot be determined due to inadequate research and data.[1]

Who is at risk?

The general population may be exposed to acrolein via breathing contaminated air, smoking, second-hand smoke, and through ingestion of certain fried foods.[1] [2] Populations living or working near fossil-fuel fired power plants and other industrial sources and also areas with high volumes of automobile traffic may be exposed to higher levels of acrolein through inhalation of polluted air.[2]

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting acrolein as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

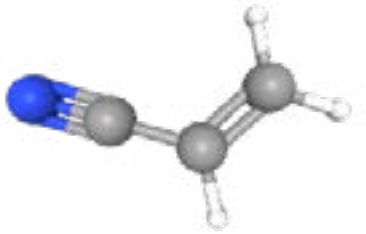
On a personal level, try to spend as little time as possible near areas of heavy vehicle traffic. If possible, avoid spending time outdoors close to busy roads and industrial facilities. Also, reduce your exposure to tobacco smoke, burning wood products, and exhaust from diesel or gasoline vehicles.[2] Also, make sure to properly use personal protective equipment.

Workers who may operate with acrolein are recommended to wear indicated personal protective equipment (PPE).[5]

5 CDC - Niosh Pocket Guide to Chemical Hazards - Acrolein. https://www.cdc.gov/niosh/npg/npgd0011.html

Acrylonitrile

What is it?



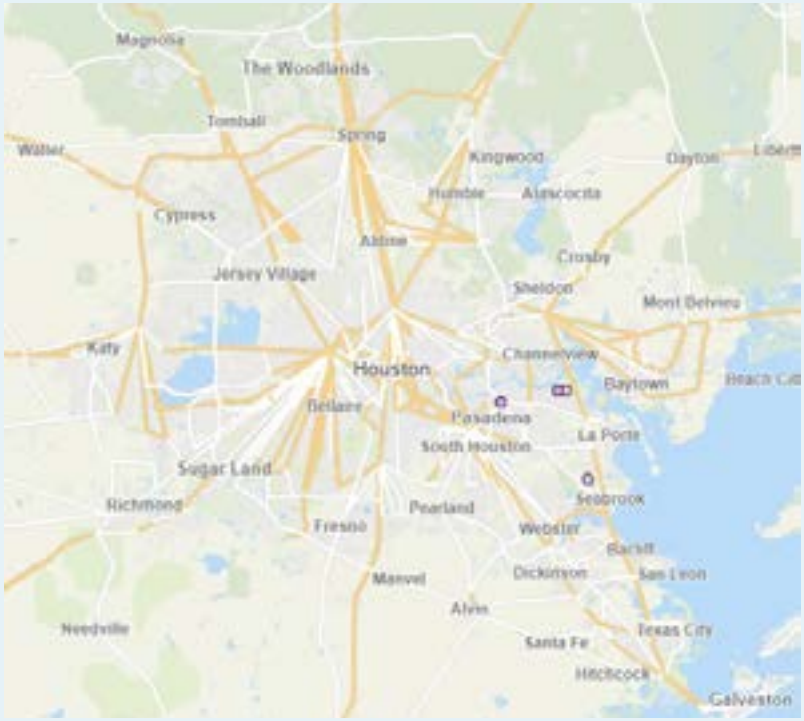
Acrylonitrile [ak-r*uh*-loh-**nahy**-tril] is a material used to create acrylic fibers, styrene plastics, resins, rubbers, and adhesives. These are used as components of nylons, clothing, furniture, appliances, motor vehicles, and food packaging.[6]

At room temperature, acrylonitrile is a clear, colorless, or slightly yellow liquid. It is volatile and forms toxic vapors at room temperature. It has an unpleasant onion or garlic-like odor. However, the smell is not a reliable warning indicator because dangerous concentrations are too low for humans to detect.[6] Therefore, you could be overexposed to acrylonitrile without knowing it's there. Only blood and urine tests can accurately assess exposure.

Emission sources

Acrylonitrile is industrially manufactured by combining propylene, ammonia, and air through a catalyst in a process called ammoxidation.

Acrylonitrile is primarily released into the environment by industrial facilities during manufacturing and use.[7] Small amounts can also be found in tobacco smoke.[8] Humans are primarily exposed to acrylonitrile via inhalation, although it can be ingested through drinking water and can irritate skin through direct contact. However, unless you work in or live near an acrylonitrile manufacturing facility or hazardous waste site, you are unlikely to be exposed.[5]



Map of acrylonitrile emitting TRI facilities in Houston (2020)

According to the EPA's NEI, the Houston area emitted approximately 20,000 pounds of acrolein in 2017. Of these emissions, approximately 91% were attributed to industrial processes (with 85% coming solely from chemical manufacturing), 7% to waste disposal and 2% to bulk gasoline terminals and solvents.[4]

6 Agency for Toxic Substances and Disease Registry. 2014. "Medical Management Guidelines for Acrylonitrile." Centers for Disease Control and Prevention. https://www.atsdr.cdc.gov/MHMI/mmg125.pdf.
7 Agency for Toxic Substances and Disease Registry. 2011. "Toxicological Profile for Acrylonitrile." Centers for Disease Control and Prevention. https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=447&tid=78.
8 World Health Organization International Agency For Research on Cancer. 1999. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 71:43-103. https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono71.pdf.

Health effects

Workers exposed to acrylonitrile reported respiratory symptoms such as nose and throat irritation, tightness in the chest, cough, and difficulty breathing.[6] [7] In fatal cases, pulmonary edema (fluid accumulation in the lungs) developed.[6]

NERVOUS SYSTEM:

Acute (short-term) exposure to acrylonitrile produces a variety of systemic effects, primarily affecting the lungs and the nervous system.

- Initial symptoms are usually general and include nervous irritability, dizziness, nausea, vomiting, headache, and limb weakness.
- If exposure continues, nervous system responses may include drowsiness, convulsions, hallucinations, loss of consciousness, and coma.[6]

CARDIOVASCULAR SYSTEM:

After entering the human body, acrylonitrile breaks down into many chemicals, including cyanide.

- People exposed to acrylonitrile may exhibit tachycardia (elevated heart rate) followed by bradycardia (low heart rate).[6] [7]
- Chemical breakdowns may lead to other negative effects on the cardiovascular system, like low blood pressure and irregular heartbeat. These compounds may also cause liver dysfunction, which can be responsible for jaundice and anorexia.[6]

INTEGUMENTARY SYSTEM:

Contact with acrylonitrile in both liquid and gaseous forms can lead to impacts on skin and eye health.

- Acrylonitrile can cause skin blisters and burns that look similar to second-degree burns.
- Eye contact with acrylonitrile can lead to irritation and increased tear production.[6]

IS THIS A CARCINOGEN?

The IARC classified acrylonitrile as a Group 2B carcinogen, meaning that it is possibly carcinogenic to humans.[6] Long-term exposure to acrylonitrile in the air or water may increase your risk of getting cancer. Studies show that workers repeatedly exposed to acrylonitrile in the workplace have a higher than average chance of developing lung cancer.[7]

Who is at risk?

People who work in industries involving acrylonitrile will be subject to greater exposures and therefore may experience more health effects.[7] Some examples of workers at greater risk of acrylonitrile exposure include factory workers making nitrile rubber products and employees who work in adhesive and coating industries.[9]

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9 The National Institute for Occupational Safety and Health. 2019. "Acrylonitrile." Center for Disease Control and Prevention. https://www.cdc.gov/niosh/topics/acrylonitrile/default.html.

Children may be more sensitive to acrylonitrile than adults. Children exposed to acrylonitrile vapor may receive larger doses because they have a larger lung surface-area-to-body-weight ratio. Acrylonitrile is heavier than air and settles closer to the ground, so children tend to inhale more vapors.[6]

What can you do?

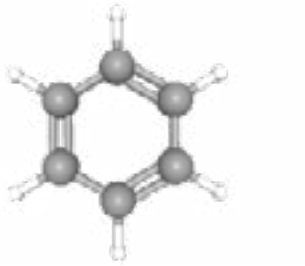
Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting acrylonitrile as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

To reduce your exposure to hexavalent chromium on a personal level, make sure to properly use personal protective equipment. Workers who may operate with acrylonitrile are recommended to wear indicated personal protective equipment (PPE).[10]

10 CDC - Niosh Pocket Guide to Chemical Hazards - Acrylonitrile. https://www.cdc.gov/niosh/npg/npgd0014.html

Benzene

What is it?

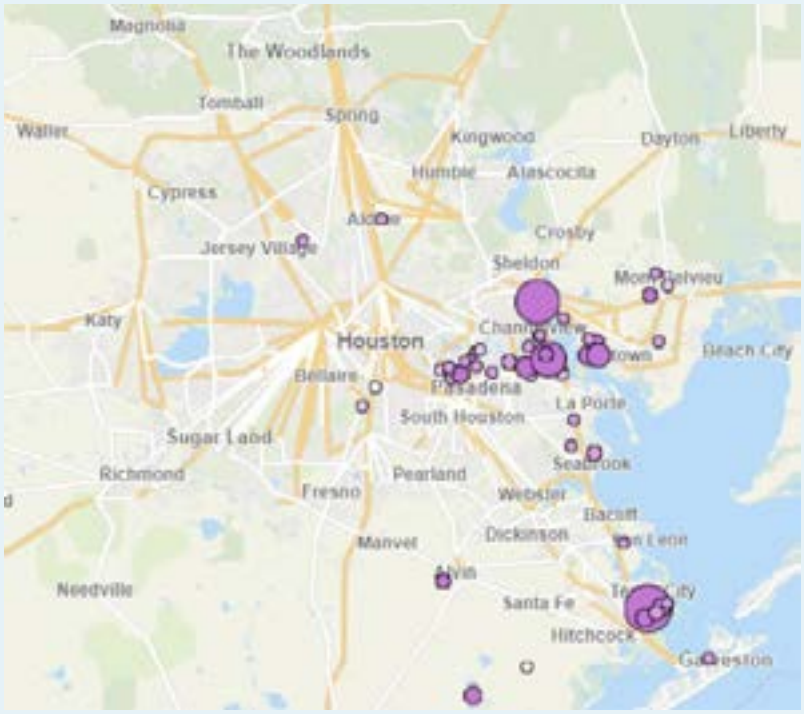


Benzene [**ben**-zeen] is a colorless liquid with a sweet smell. As a volatile organic compound (VOC), it evaporates into the air very quickly. It is also highly flammable and dissolves slightly in water. Since it is a widely used chemical formed from both natural and man-made processes, benzene is found in air, water, and soil.[11]

Benzene has a wide variety of uses, including as a component in motor fuels, as a solvent for fats, as a component of plastics/rubber, and as a chemical intermediate. It is also used to manufacture pharmaceuticals, detergents, and pesticides.[11] [12]

Emission sources

Benzene is produced industrially through four petrochemical processing mechanisms: catalytic reforming, toluene hydrodealkylation, toluene disproportionation, and steam cracking. Most benzene produced is made from petroleum. Due to its widespread use across industries, benzene ranks in the top 20 chemicals nationally for production volume.[13]



Map of benzene emitting TRI facilities in Houston (2020)

Industrial processes are the main source of human-made benzene in the environment. Emissions are often caused by burning fossil fuels, petroleum refining operations, benzene waste and storage operations, motor vehicle exhaust, and evaporation from gasoline stations. Other sources of exposure include gaseous vapors from products that contain benzene like glues, paints, and detergents. Cigarette smoking accounts for approximately half of the total benzene exposure of the U.S. population.[11]

According to the EPA's NEI, the Houston area emitted approximately 1,540,000 pounds of benzene in 2017. Of these emissions, approximately 65% were attributed to mobile sources (such as automobile traffic), 26% to industrial sources, 4% to bulk gasoline terminals, and 2% to fuel combustion sources.[4]

11 Agency for Toxic Substances and Disease Registry. 2007. "Toxicological Report for Benzene." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp3.pdf.
12 United States Environmental Protection Agency. 2016. "Benzene Hazard Summary." United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2016-09/documents/benzene.pdf.
13 Centers for Disease Control and Prevention. 2018. "Facts about Benzene". https://emergency.cdc.gov/agent/benzene/basics/facts.asp.

Despite having natural sources – such volcanoes and forest fires – human-made industrial sources such as those outlined above contribute to the vast majority of benzene in the air.[11]

Health effects

Inhalation is the major route of exposure for benzene. Acute (short-term) exposure to lower concentrations can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness.

Usually, once people are removed from the benzene exposure and breathe fresh air, they will stop feeling these effects.[12]

REPRODUCTIVE SYSTEM:

It is currently unknown whether or not benzene causes male reproductive issues.[12]

- In a study of female workers exposed to high levels of benzene, researchers found that the participants had irregular menstrual cycles as a result of decreased ovary size.[11] However, it is not certain that benzene caused these effects.
- Animal studies show that breathing in benzene has harmful effects on a developing fetus, including low birth weight, delayed bone formation, and bone marrow damage.[11]

GENOTOXICITY:

Data from both human and animal studies indicate that benzene is genotoxic, meaning that it is toxic to our genes. Chromosomal abnormalities such as deletions and breaks in peripheral white blood cells and bone marrow cells are the predominant effects seen in humans.[11]

LYMPHATIC AND IMMUNE SYSTEM:

- Benzene causes harmful effects in the tissues that make blood, especially the bone marrow. These effects interrupt normal blood production and cause decreases in blood components.
- A decrease in red blood cells can lead to anemia while a decrease in other components can cause excessive bleeding.
- Excessive exposure to benzene can harm the immune system, increasing the chance for infection and potentially lowering the body's defense against cancer.[11]

IS THIS A CARCINOGEN?

The IARC has classified benzene as a Group 1 carcinogen, meaning that it causes cancer in humans.[14] Long-term exposure to benzene can lead to cancer of the blood-forming organs, also known as leukemia. Benzene exposure has also been associated with a specific type of leukemia called acute myeloid leukemia (AML).[11] [15]

Who is at risk?

People living in cities or industrial areas are usually exposed to higher levels of benzene in the air compared to those living in rural areas. Those living near hazardous waste sites, petroleum refining

14 Agency for Toxic Substances and Disease Registry. 2015. "Medical Management Guidelines for Benzene." Centers for Disease Control and Prevention. https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=35&toxid=14.

15 International Agency for Research on Cancer. 2018. "BENZENE." IARC Monographs on the Identification of Carcinogenic Hazards to Humans. https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono100F-24.pdf.

operations, petrochemical operations, manufacturing sites, and gas stations may also be exposed to higher levels of benzene. Additionally, smokers are subject to significantly higher levels of benzene. Children exposed to the same levels of benzene vapor as adults may receive larger doses because they possess greater lung surface-area-to-body ratios and are lower to the ground, where benzene vapor tends to be found.[14]

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting benzene as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

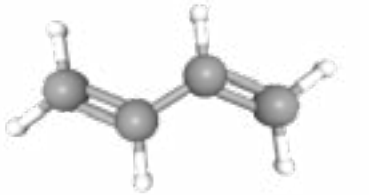
You can decrease benzene exposure on a personal level by decreasing or stopping cigarette use, especially indoors. Additionally, reducing direct contact with gasoline will help to decrease benzene exposure.[11]

Make sure to also properly use personal protective equipment. Workers who may operate with benzene are recommended to wear indicated personal protective equipment (PPE).[16]

16 CDC - Niosh Pocket Guide to Chemical Hazards - Benzene. https://www.cdc.gov/niosh/npg/npgd0049.html

1,3-Butadiene

What is it?

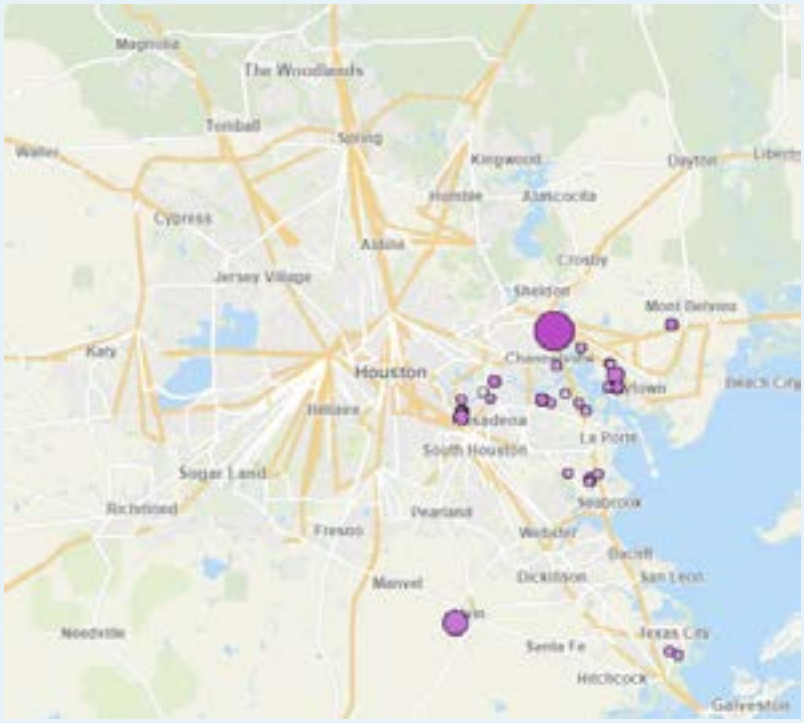


1,3-Butadiene [byoo-t*uh*-**dahy**-een] is a highly reactive, colorless gas with a mild, gasoline-like odor.[17] In addition to the toxic properties of 1,3-Butadiene, the chemical is a VOC that contributes to ozone formation.[18] 1,3-Butadiene is mostly used to produce synthetic rubbers, which are then used in industrial and consumer products like tires, resins, and protective clothing. 1,3-Butadiene is also used to produce petrochemicals and plastics like shock-resistant polystyrene.

Emission sources

In the United States, 1,3-Butadiene is primarily produced through the processing of petroleum as a by-product during the ethylene production process. It is the 36th highest volume chemical produced in the United States.[19]

Larger sources of 1,3-Butadiene include industrial facilities and motor vehicle exhaust. As a result, greater 1,3-Butadiene levels tend to be found in highly industrialized cities, near oil refineries, chemical manufacturing plants, and plastic and rubber factories. Other sources include forest fires, cigarette smoke and other types of combustion.[20] [21]



Map of 1,3-butadiene emitting TRI facilities in Houston (2020)

According to the EPA's NEI, the Houston area emitted approximately 526,000 pounds of 1,3-Butadiene in 2017. Of these emissions, approximately 58% were attributed to industrial sources, 37% to mobile sources, 2% to bulk gasoline terminals, and 2% to fuel combustion sources.[4]

17 Ashizawa, Annette, Diana Cronin, Carolyn Harper, Lisa Ingerman, Nickolette Roney, and Pamela G. Tucker. "Toxicological profile for 1, 3-butadiene." (2012).
18 Czader, Beata H., and Bernhard Rappenglück. "Modeling of 1,3-butadiene in urban and industrial areas." *Atmospheric Environment* 102 (2015): 30-42.
19 ATSDR. Toxic Substances Portal. 1,3-Butadiene: https://wwwn.cdc.gov/TSP/substances/ToxSubstance.aspx?toxid=81
20 International Agency for Research on Cancer. 2018. "1,3-BUTADIENE." IARC Monographs on the Identification of Carcinogenic Hazards to Humans. https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono100F-26.pdf.
21 Gordon, Sydney M., Lance A. Wallace, Marielle C. Brinkman, Patrick J. Callahan, and Donald V. Kenny. "Volatile organic compounds as breath biomarkers for active and passive smoking." *Environmental health perspectives* 110, no. 7 (2002): 689-698.

Health effects

People are usually exposed to 1,3-Butadiene through inhalation. In animal studies, 1,3-Butadiene is linked with a wide range of non-cancer health effects, such as nasal inflammation, changes to lung, heart, and reproductive tissues, brain and behavioral effects, and blood changes. In studies conducted on mice, 1,3-Butadiene caused reproductive and developmental effects, including ovarian atrophy and deterioration. However, there is currently no human data on these effects.[17]

RESPIRATORY AND INTEGUMENTARY SYSTEM:

In a study involving industrial rubber workers, those acutely exposed to 1,3-Butadiene gas experienced eye, nose, throat, and lung irritation. In some, coughing, fatigue, and drowsiness also developed.

NERVOUS SYSTEM:

Blurred vision, fatigue, headache, and vertigo have also been reported at very high exposure levels.

CARDIOVASCULAR SYSTEM:

- Chronic (long-term) exposure to 1,3-Butadiene via inhalation may lead to an increase in cardiovascular diseases and excess mortality from rheumatic and arteriosclerotic heart diseases.
- Studies have also found that chronic exposure may affect the blood and liver.[17] [22]

IS THIS A CARCINOGEN?

The IARC has classified 1,3-Butadiene a Group 1 carcinogen. There is evidence showing that greater exposure can lead to increased risk for hematolymphoid malignancies – cancers of the blood-forming tissues or cells in the immune system. 1,3-Butadiene has also been linked to excess leukemia deaths in workers and an elevated incidence of leukemia cases among children in Southeast Texas.[20]

22 Mosby. 2009. *Mosby's Dictionary of Medicine, Nursing & Health Professions*. 8th ed. St. Louis: Elsevier.

Who is at risk?

The highest 1,3-Butadiene exposures occur in occupational settings. Workers in industrial activities like petroleum refining and rubber manufacture have the greatest chance of being exposed.[20] Residents who live near industrial facilities like oil refineries, chemical manufacturing plants, or plastic and rubber factories have an elevated risk of exposure to 1,3-Butadiene as well.[17]

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting 1,3-Butadiene as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

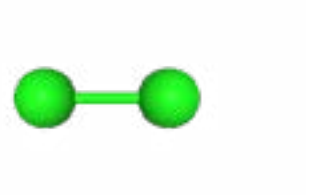
To reduce your exposure to 1,3- Butadiene on a personal level, try to spend as little time as possible near areas of heavy vehicle traffic, busy roads, and industrial facilities. If you cannot avoid these areas, make sure to properly use personal protective equipment. Workers who may operate with 1,3-Butadiene are recommended to wear indicated Personal Protective Equipment (PPE).[23]

Additionally, ensure proper ventilation from wood-burning fireplaces and when you are in an enclosed space like a garage, make sure to turn off all vehicle engines. Lastly, avoid tobacco smoke, especially when indoors.[17]

23 CDC - Niosh Pocket Guide to Chemical Hazards - 1,3-Butadiene. https://www.cdc.gov/niosh/npg/npgd0067.html

Chlorine

What is it?

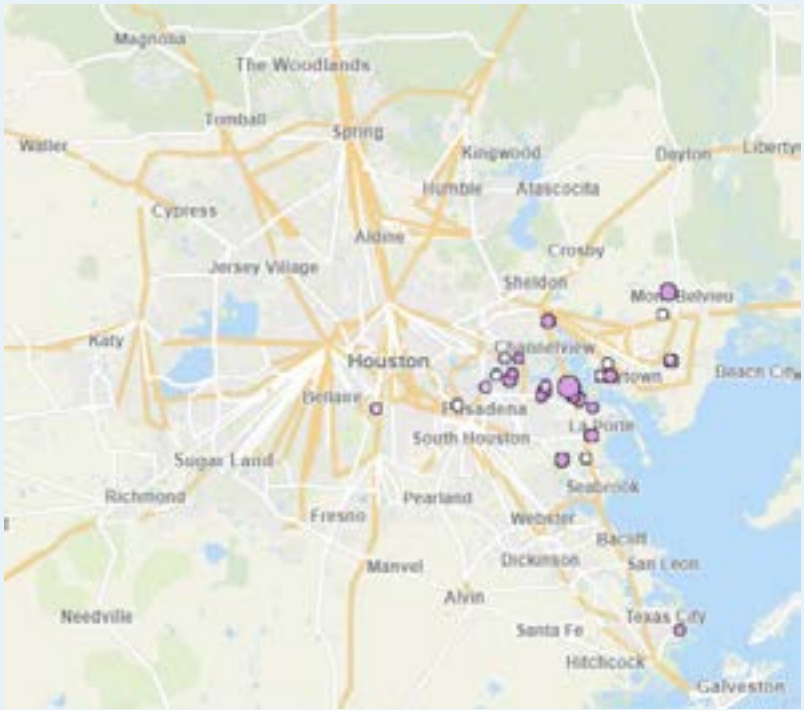


Chlorine [**klohr**-een] is a greenish-yellow gas with a pungent, irritating odor similar to bleach.[24] It is one of the most commonly manufactured chemicals in the United States and is widely used in industry and as an ingredient of household products like bleach.[24 25] When shipped, it is pressurized and cooled to change it into a clear, amber liquid.[24 26] When the liquid is released, it turns into a gas that stays close to the ground and quickly spreads. In gas form, chlorine is poisonous.[24 26] The most important use of chlorine is as bleach when producing paper and cloth. Chlorine is also vital for killing harmful bacteria in swimming pools and for being a part of the sanitation process for industrial waste and sewage.[24]

Emission sources

Most chlorine is manufactured electrolytically by the diaphragm, membrane, or mercury cell process. In each process, a salt solution (sodium or potassium chloride) is electrolyzed by the action of direct electric current which converts chloride ions to elemental chlorine.

Chlorine exposure usually occurs during accidents such as a chlorine tank rupture at a facility or a liquid chlorine spill during transportation. When chlorine is released during these types of incidents, it will react with other chemicals in the air to form a greenish-yellow chlorine gas cloud, which may expose nearby populations to high levels of gas through inhalation.[25] Additionally, people who mix acidic solutions with bleach or certain types of swimming pool chemicals may accidentally be exposed to chlorine gas.



Map of chlorine emitting TRI facilities in Houston (2020)

According to the EPA's NEI, the Houston area emitted approximately 40,000 pounds of chlorine in

24 Center for Disease Control and Prevention. 2018. "Facts About Chlorine." Center for Disease Control and Prevention. https://emergency.cdc.gov/agent/chlorine/basics/facts.asp.
25 Agency for Toxic Substances and Disease Registry. 2010. "Toxicological Profile for Chlorine." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp172.pdf.
26 Agency for Toxic Substances and Disease Registry. 2014. "Medical Management Guidelines for Chlorine." Centers for Disease Control and Prevention. https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=198&toxid=36.

2017. Of these emissions, approximately 96% were attributed to industrial sources (with 85% coming solely from chemical manufacturing) and 3% to fuel combustion sources.[4]

Health effects

The toxic effects of chlorine occur due to its corrosive properties.[26] The main targets of chlorine gas are the respiratory airways and the eyes. Long-term exposure to chlorine, usually in workers, may cause corrosion of the teeth.

RESPIRATORY AND INTEGUMENTARY SYSTEM:

- Exposure to low concentrations of chlorine may cause eye and nose irritation, sore throat, and coughing.[25] [26]
- At higher concentrations, inhaling chlorine gas can produce immediate chest pain, nausea and vomiting, shortness of breath, cough, and buildup of fluid in the lungs (pulmonary edema). Inhaling chlorine gas can be fatal, but only if you're exposed to extremely high concentrations.[25] [26]
- Additionally, multiple exposures to chlorine have led to flu-like symptoms and a high risk of developing reactive airways dysfunction syndrome (RADS).[26]

IS THIS A CARCINOGEN?

Chlorine has not been implicated in cancer studies. The EPA, IARC and the Department of Health and Human Services (DHHS) have not classified chlorine for carcinogenicity[25] due to a lack of data.

Who is at risk?

The elderly, smokers, and persons with chronic pulmonary disease may be at greatest risk for breathing problems following acute exposure.[27]

However, people in occupations that use chlorine may be exposed to greater concentrations than the general public, such as workers in water treatment and sewage facilities, bleach and plastics manufacturing industries, workers who use cleaning products, clean pools, and/or clean livestock facilities, such as dairy farms.[28]

What can you do?

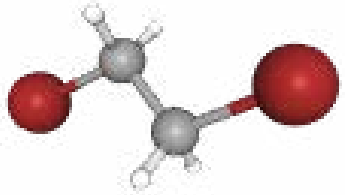
Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting chlorine as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

To reduce your exposure to chlorine on a personal level, make sure to properly use personal protective equipment. Workers who may operate with chlorine are recommended to wear indicated personal protective equipment (PPE).[29] In the event of a chlorine leak or accident, leave the area where the chlorine was released and get to fresh air. Go to the highest ground possible because chlorine is heavier than air and will sink to low-lying areas. If the chlorine release was indoors, get out of the building.

27 Michigan Department of Community Health. Chlorine - Public Fact Sheet. https://www.michigan.gov/-/media/Project/Websites/mdhhs/Folder1/Folder23/Chlorine_fact_sheet.pdf?rev=9554e6cee85442ae8519902c91bd066e
28 CDC - NIOSH Workplace Safety and Health Topics - Chlorine. https://www.cdc.gov/niosh/topics/chlorine/default.html
29 CDC - NIOSH Pocket Guide to Chemical Hazards - Chlorine. https://www.cdc.gov/niosh/npg/npgd0115.html

1,2-Dibromoethane

What is it?

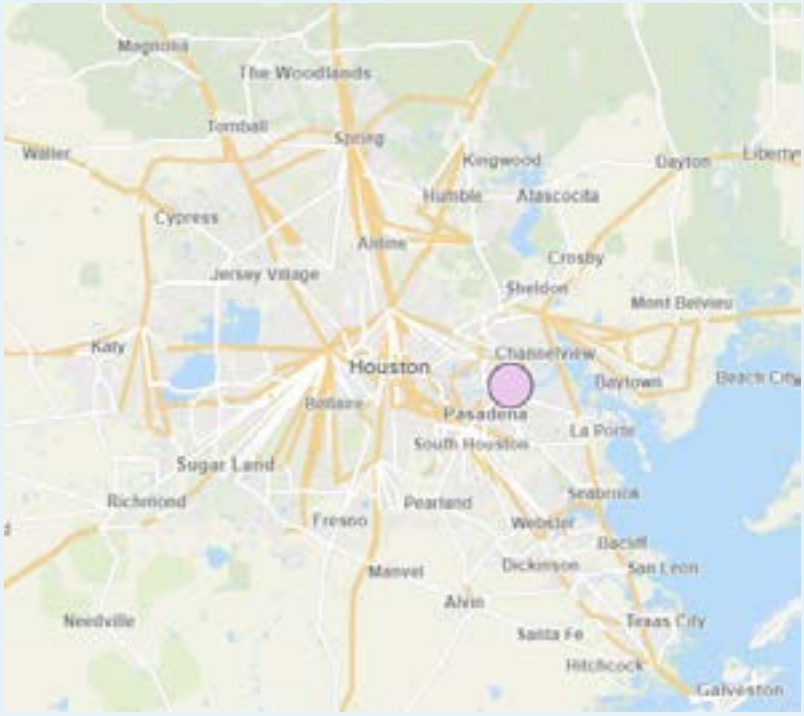


1,2-Dibromoethane [dahy-**broh**-mo-**eth**-**eyn**] is a colorless liquid with a mild, sweet odor. Historically, it was used as an additive in leaded gasoline and as a fumigant pesticide – but no longer. Currently, 1,2-Dibromoethane is used as a pesticide treatment of felled logs and beehives as well as an intermediate in dye, resin, gum, and wax production.[30] Its trade names include Bromofume and Dowfume.[31]

Emission sources

1,2-Dibromoethane is produced when gaseous ethylene comes in contact with bromine. One of the more common manufacturing processes involves a liquid-phase bromination of ethylene, which is then followed by the mixture being neutralized then purified by distillation.

The primary sources of airborne 1,2-Dibromoethane are industrial production and processing facilities.[21] Waste sites containing 1,2-Dibromoethane can also pollute surrounding waters and soils. Exposure to 1,2-Dibromoethane may occur by breathing in contaminated air or by drinking or touching contaminated water, especially well water near industrial waste sites or farms. Children in particular can be exposed by playing in soils at or near waste sites containing 1,2-Dibromoethane.[31]



Map of 1,2-Dibromoethane emitting TRI facilities in Houston (2020)

According to the EPA's NEI, the Houston area emitted 454 pounds of 1,2-Dibromoethane in 2017, sourced entirely from industrial processes, with 95% coming solely from petroleum refineries.[4]

30 Agency for Toxic Substances and Disease Registry. 2018. "Toxicological Profile for 1,2-Dibromoethane." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp37.pdf.
31 Agency for Toxic Substances and Disease Registry. 1999. "1,2-Dibromoethane ToxFAQs." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxfaqs/tfacts134.pdf.

Health effects

Exposure to 1,2-Dibromoethane can cause serious systemic health effects, including in the liver, kidneys, gastrointestinal tract, and reproductive organs.

RESPIRATORY SYSTEM:

Respiratory symptoms of 1,2-Dibromoethane inhalation include nose and throat irritation.

- Moderate to severe exposures to 1,2-Dibromoethane may produce respiratory issues ranging from cough, chest pain, and shortness of breath to bronchitis, pulmonary edema (excess fluid in lungs), and hemorrhage.[32]

LYMPHATIC AND NERVOUS SYSTEM:

- 1,2-Dibromoethane may also impact the brain and spinal cord. Workers have reported that inhaling 1,2-Dibromoethane led to drowsiness and confusion.[30]
- The inhalation of vapors in a confined, oxygen-deprived space has caused unconsciousness, coma, and even death.[32]

INTEGUMENTARY SYSTEM:

- Liquid 1,2-Dibromoethane is a skin irritant. In worker studies, skin contact led to erythema (skin redness) and discomfort. Prolonged contact may cause blistering and skin ulcers.[30 32]

GASTROINTESTINAL SYSTEM:

- Inhalation or ingestion of 1,2-Dibromoethane has resulted in liver failure and necrosis.
- In several cases of 1,2-Dibromoethane poisoning, lesions in the kidneys were reported.
- Ingesting 1,2-Dibromoethane can also cause vomiting, diarrhea, nausea, and abdominal pain.
- In animal studies, ingestion led to gastrointestinal lesions.

REPRODUCTIVE SYSTEM:

- Worker studies show that inhalation and oral exposure to 1,2-Dibromoethane may lead to infertility and damage to male reproductive organs and sperm. Animal research indicates similar reproductive health outcomes.[30 32]

IS THIS A CARCINOGEN?

- The IARC has classified 1,2-Dibromoethane as a Group 2A carcinogen, meaning that it is "probably carcinogenic to humans." This means that there is inadequate evidence for carcinogenicity in humans, but that there is adequate evidence for carcinogenicity in animals.[33] Animal studies indicate that oral exposure may lead to endocrine cancer outcomes, while inhalation may cause reproductive and respiratory cancer outcomes.[30]

Who is at risk?

Generally, your exposure to 1,2-Dibromoethane is much lower than levels that can harm you. However, people in occupations that use 1,2-Dibromoethane may be exposed to greater concentrations than the general public.[31] Additionally, people at higher risk include those with pre-existing skin disorders,

32 Agency for Toxic Substances and Disease Registry. 2014. "Medical Management Guidelines for Ethylene Dibromide." Centers for Disease Control and Prevention. https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=1143&toxid=251.

33 World Health Organization International Agency For Research on Cancer. 1999. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans.* Vol. 71:(641):669. https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono71.pdf.

eye problems, and impaired liver, kidney, and respiratory tract function. Children may also be more vulnerable due to higher lung surface-area-to-body ratio.[32]

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting 1,2-Dibromoethane as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

If you live close to an industrial facility that produces dyes, resins, gums, or waxes, try to avoid letting your children play in nearby soil and swimming in nearby waters. Additionally, 1,2-Dibromoethane can permeate clothing, leather, and regular rubber, so if exposed, make sure to remove contaminated clothing and rinse your skin thoroughly with soap and water.[32]

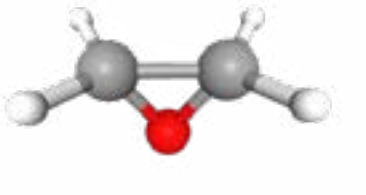
To reduce your exposure to 1,2-Dibromoethane on a personal level, make sure to properly use personal protective equipment. Workers who may operate with 1,2-Dibromoethane are recommended to wear indicated personal protective equipment (PPE).[34]

34 CDC - Niosh Pocket Guide to Chemical Hazards - 1,2-Dibromoethane. https://www.cdc.gov/niosh/npg/npgd0270.html

Ethylene Oxide

What is it?

Ethylene oxide [**eth**-*uh*-leen **ok**-sahyd] is a flammable, colorless gas, with a somewhat sweet odor. It is used to sterilize medical equipment and also as a building block for other chemicals to manufacture a range of products, such as antifreeze, textiles, plastics, detergents, and adhesives.[35]

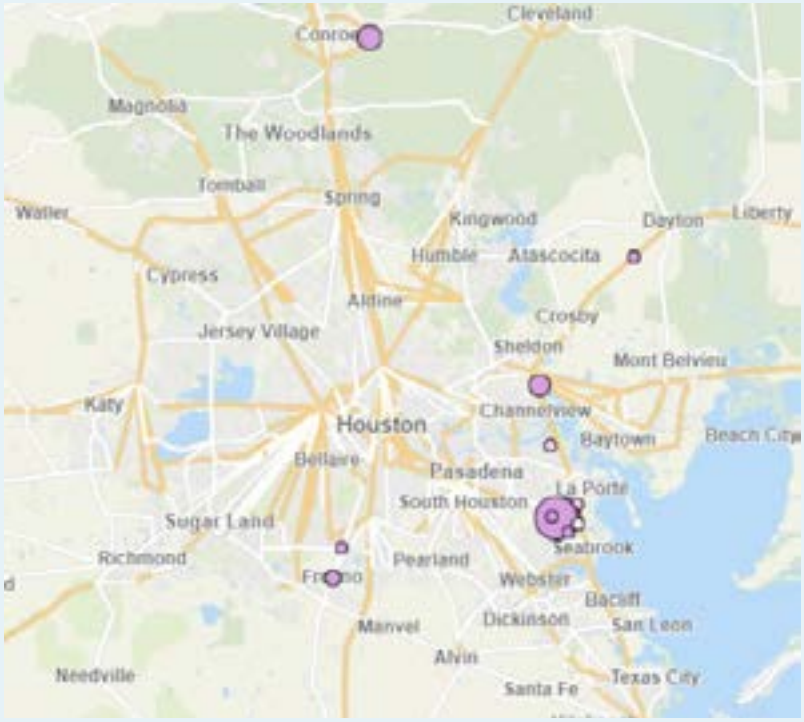


Emission sources

Ethylene oxide is industrially produced by oxidation of ethylene in the presence of silver catalyst.

Ethylene oxide in the air can come from different types of sources, including industries such as chemical manufacturers and sterilizers. People may also be exposed to ethylene oxide through tobacco smoke and the use of products that have been sterilized with ethylene oxide, including medical products.[36]

According to the EPA's NEI, the Houston area emitted approximately 16,000 pounds of ethylene oxide in 2017, sourced almost entirely from industrial processes, with over 95% coming solely from chemical manufacturing.[4]



Map of ethylene oxide emitting TRI facilities in Houston (2020)

Health effects

Just short-term exposure may lead to irritation of the eyes and neurological impacts while chronic long-term exposure can more severely damage your eyes, skin, nose, throat, lungs, and harm the brain and neurological system.[37]

35 United States Environmental Protection Agency. 2017. "Ethylene oxide CASRN 75-21-8 | DTXSID0020600." EPA.gov. https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=1025.
36 National Cancer Institute. 2018. "Ethylene Oxide." Cancer.org. https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/ethylene-oxide.
37 United States Environmental Protection Agency. 2021. "Hazardous Air Pollutants: Ethylene Oxide." Epa.gov. https://www.epa.gov/hazardous-air-pollutants-ethylene-oxide.

IS THIS A CARCINOGEN?

Breathing air contaminated with ethylene oxide over many years can increase the risk of some types of cancers, including various lymphoid cancers and breast cancer.[36] The EPA concluded in late 2016 that ethylene oxide is at least 30 times more carcinogenic than previously understood.[25] The IARC has classified ethylene oxide as a Group 1 carcinogen.[38]

Who is at risk?

The highest ethylene oxide exposures occur in close proximity to facilities emitting the chemical. Therefore, workers at and those who live near industrial facilities that produce or use ethylene oxide have an elevated risk of exposure.[36]

What can you do?

Find out if you live near an EtO emitting facility using this tool (enter "ethylene oxide" under Filters > Chemical) and also review the list of facilities in this OIG report (page 11). If so, find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting ethylene oxide. Additionally, request expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

To reduce your exposure to ethylene oxide on a personal level, make sure to properly use personal protective equipment. Workers who may operate with ethylene oxide are recommended to wear indicated personal protective equipment (PPE).[39]

There is little you can otherwise do personally to reduce ethylene oxide levels. If you live near one of the above facilities, it may be beneficial to reduce your time outdoors and avoid heavy exercise in the area. You can also stay updated with the EPA's actions on regulating ethylene oxide by following this web page.

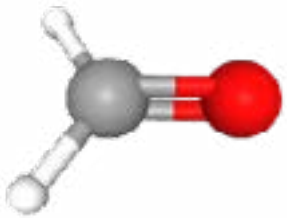
38 International Agency for Research on Cancer. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 100: A Review of Human Carcinogens Part F: Chemical Agents and Related Occupations*. 2012. https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono100F-28.pdf

39 CDC - Niosh Pocket Guide to Chemical Hazards - Ethylene Oxide. https://www.cdc.gov/niosh/npg/npgd0275.html

Formaldehyde

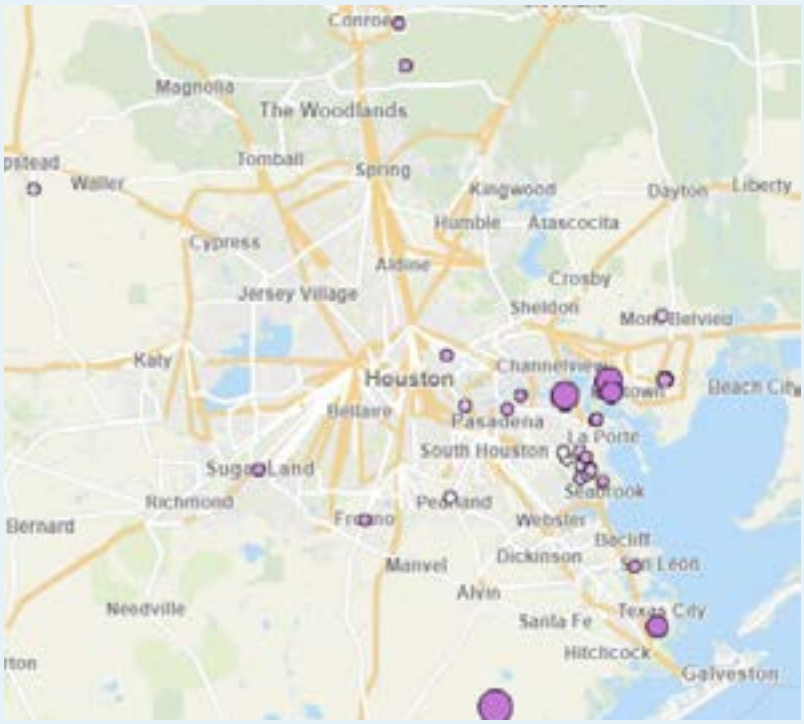
What is it?

Formaldehyde [fawr-**mal**-d*uh*-hahyd] is a colorless, flammable gas at room temperature with a strong, distinct odor. An ever-present chemical, formaldehyde is found in commercial products including cigarettes, carpets, cosmetics, wood products, medicines, and preserved foods. Industrially, formaldehyde is used to make resins for wood products, fertilizer, paper, and plywood.



Emission sources

There are several industrial formaldehyde production processes, though generally it is produced by the vapor-phase oxidation of methanol. The different processes following that stage affect the concentration level of the produced formaldehyde.



Map of formaldehyde emitting TRI facilities in Houston (2020)

For the general population, the major sources of formaldehyde include combustion sources, tobacco smoke, home goods, and consumer goods. Combustion sources include automobiles, power plants, and oil refineries.[40] Home goods that release formaldehyde into the air include wood pressed products made with urea-formaldehyde resins, particleboard, and plywood.[40] [41] Consumer products that release formaldehyde include cosmetics, soaps, and household cleaning agents.[40] Additionally, preexisting air pollutants will react with each other to create secondary formaldehyde. Because there is a great diversity in air pollutants that will react to create formaldehyde, the amount of secondary formaldehyde in the air may exceed that which is directly emitted from cars and industrial sources.[40]

According to the EPA's NEI, the Houston area emitted approximately 2,506,000 pounds of formaldehyde in 2017. Of these emissions, approximately 44% were attributed to mobile sources (such as automobile traffic), 43% to biogenic sources (emissions from natural sources such as vegetation and soils), 8% to fuel combustion sources, 2% to commercial cooking, and 2% to industrial sources.[4]

40 Costa, Solange, and J. P. Teixeira. "Formaldehyde: Human exposure, metabolism and potential health effects." *Formaldehyde: Synthesis, Applications and Potential Health Effects* (2015): 1-29.
41 Agency for Toxic Substances and Disease Registry. 1999. "Toxicological Report for Formaldehyde." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxprofiles/tp111.pdf.

Health effects

People are usually exposed to formaldehyde through inhalation.

RESPIRATORY AND INTEGUMENTARY SYSTEM:

Vapors can cause irritation of the eyes, nose, and throat, with eye irritation being the most sensitive. Other symptoms of exposure include sneezing, coughing, sore throat, increased tear production, and nausea.[41]

NERVOUS SYSTEM:

Studies report that exposure to formaldehyde may decrease performance in short-term memory tests and impair the ability to concentrate.[37] [41]

GENOTOXICITY:

Studies have reported an increased frequency of abnormal DNA outcomes and DNA damage in formaldehyde-exposed workers, namely those who are most at-risk: industry workers, embalmers, and pathology and anatomy workers. Studies have also suggested that these toxic interactions between formaldehyde and DNA may ultimately lead to cancer formation.[40]

IS THIS A CARCINOGEN?

The IARC has classified formaldehyde as a Group 1 carcinogen.[42] Studies have shown that exposure to formaldehyde can cause an increased risk of leukemia and nasopharyngeal cancer (cancer of the upper part of the throat). In addition, there may be a link between exposure to formaldehyde and sinonasal cancer, a rare cancer affecting the nasal cavity and sinuses.[40] [41]

Who is at risk?

Work environments are usually the largest source of airborne formaldehyde. The occupational groups considered to be most at risk are industrial workers from chemical industries and plywood factories, embalmers, and pathology and anatomy laboratory workers. Additionally, those with asthma may be at risk for worsening symptoms if exposed to formaldehyde for long periods of time.[41]

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting formaldehyde as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

To reduce your exposure to formaldehyde on a personal level, make sure to properly use personal protective equipment. Workers who may operate with formaldehyde are recommended to wear indicated personal protective equipment (PPE).[43]

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42 International Agency for Research on Cancer. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Volume 100: A Review of Human Carcinogens Part F: Chemical Agents and Related Occupations*. 2012. https://monographs.iarc.who.int/wp-content/uploads/2018/06/mono100F-29.pdf

43 CDC - Niosh Pocket Guide to Chemical Hazards - Formaldehyde. https://www.cdc.gov/niosh/npg/npgd0293.html

Formaldehyde levels are usually higher indoors, so ventilating the home by opening windows or using fans is the easiest way to lower formaldehyde levels. Additionally, limit the use of pressed wood in homes or seal uncovered pressed wood products to reduce the amount of formaldehyde that is released.[41] If possible, use lower-emitting pressed wood products certified as CARB (California Resource Board) Phase 1 or 2 compliant, or made with ULEF (ultra-low- emitting formaldehyde) or NAF (no-added formaldehyde) resins.[44]

Formaldehyde is a component of tobacco smoke. If possible, reduce or avoid smoking cigarettes in enclosed spaces such as inside the home or car to limit exposure to children and other family members. Lastly, some permanent-press fabrics emit formaldehyde. So, washing new clothes before wearing them will lower the amount of formaldehyde released and reduce exposure to families.[41]

44 National Institute of Environmental Health Sciences. 2021. "Formaldehyde." National Institute of Environmental Health Sciences. https://www.niehs.nih.gov/health/topics/agents/formaldehyde/index.cfm.

Hexavalent Chromium

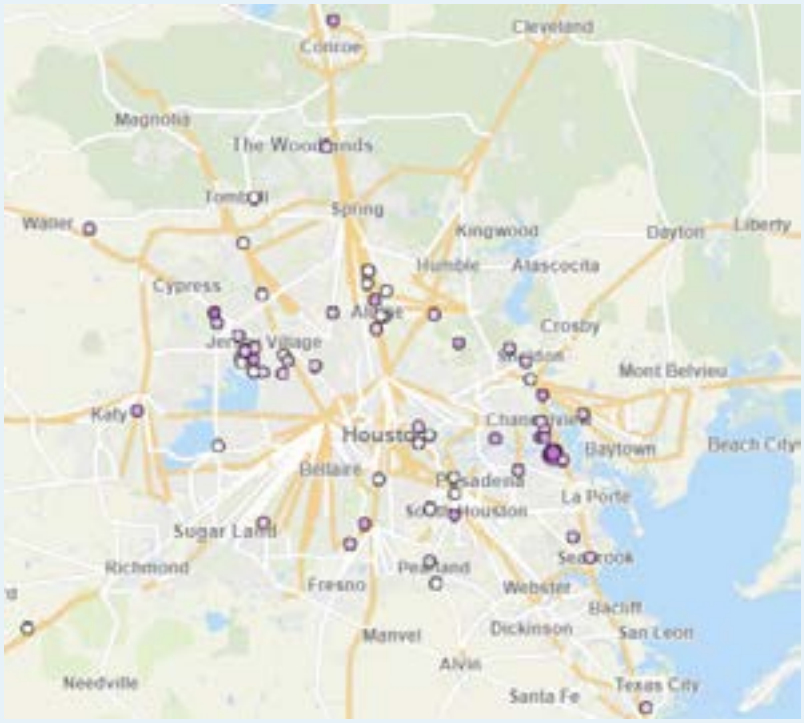
What is it?

Hexavalent Chromium [**hek**-*suh*-vey-l*uh*nt **kroh**-mee-*uh*m] is a form of Chromium. Chromium is a naturally occurring metal found in rocks, animals, plants, and soil. The two main forms of chromium are trivalent chromium (Chromium III) and hexavalent chromium (Chromium VI).[45] These compounds have no identifying taste or odor.[46] Trivalent chromium is an essential nutrient whereas hexavalent chromium is produced through industrial processes and is harmful to human health. Hexavalent Chromium is used in industries like electroplating and stainless-steel production.[45] As a result, chromium is found in products such as stainless-steel cookware, metal-on-metal hip replacements, and wood treated with copper dichromate.

Cr^{6+}

Emission sources

Hexavalent chromium, or chromium (VI), is generally released by industrial processes that utilize chromium compounds. For example, Hexavalent chromium can be formed when performing "hot work" such as welding on stainless steel or melting chromium metal. In these situations the chromium is not originally hexavalent, but the high temperatures involved in the process result in oxidation that converts the chromium to a hexavalent state.[47]



Map of chromium and chromium compound emitting TRI facilities in Houston (2020)

Chromium in the air occurs from industrial processes, metal working, and the burning of fossil fuels and pressure-treated wood. The most important industrial source of hexavalent chromium in the atmosphere is ferrochrome production. Ore refining, cement-producing plants, and catalytic converters for automobiles are some examples that contribute to chromium compounds in the atmosphere.[48] People are usually exposed to hexavalent chromium through inhalation, ingestion

45 U.S. Department of Health and Human Services and Agency for Toxic Substances and Disease Registry. 2012. "Toxicological Profile for Chromium." National Center for Biotechnology Information. https://www.ncbi.nlm.nih.gov/books/NBK158855/pdf/Bookshelf_NBK158855.pdf.
46 Agency for Toxic Substances and Disease Registry. 2012. "Chromium-ToxFAQs." Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov/toxfaqs/tfacts7.pdf.
47 Occupational Safety and Health Administration. n.d. "1910.1026 - Chromium (VI) | Occupational Safety and Health Administration." United States Department of Labor. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1026.
48 US Environmental Protection Agency. 1998. "Toxicological Review of Trivalent Chromium." US Environmental Protection Agency. https://cfpub.epa.gov/ncea/iris/iris_documents/documents/toxreviews/0028tr.pdf

through food or water, or bare skin touch. The most common route of exposure to elevated levels of hexavalent chromium is from indoor cigarette smoke.[45]

According to the EPA's NEI, the Houston area emitted approximately 560 pounds of hexavalent chromium in 2017. Of these emissions, approximately 74% were attributed to industrial sources, 21% to fuel combustion sources, 3% to solvents, and 2% to waste disposal.[4]

Health effects

RESPIRATORY SYSTEM:

- Breathing problems such as coughing, shortness of breath, runny nose, and wheezing.
- While more research is needed, many studies indicate that chronic exposure to hexavalent chromium may induce respiratory diseases such as bronchitis, pneumonia, and asthma.

GASTROINTESTINAL SYSTEM:

- Oral consumption in food and water can lead to abdominal pain, vomiting, indigestion, and bloody diarrhea.
- In animal studies, hexavalent chromium produced stomach, intestine, and lung tumors.[45]
- Long-term inhalation or oral exposure to hexavalent chromium can produce effects on the liver, kidney, gastrointestinal tract, immune system, and potentially the blood.[45 46 49]

INTEGUMENTARY SYSTEM:

- Dermal contact can produce effects such as irritation, burns, and allergic eczema.[46]

IS THIS A CARCINOGEN?

The IARC has classified hexavalent chromium as a Group 1 carcinogen. Occupational exposure is associated with increased risk of respiratory cancers.

Who is at risk?

Workers in chromate production, stainless steel production, chrome plating, welding, and tanning industries are exposed to much greater concentrations of hexavalent chromium compared with the general population. Additionally, those who live close to waste disposal and recycling sites that process chromium-containing materials or chromium manufacturing and processing plants are more likely to be exposed to greater amounts of hexavalent chromium.[45]

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49 National Toxicology Program. 2018. "Hexavalent Chromium." National Institute of Environmental Health Sciences. https://www.niehs.nih.gov/health/materials/hexavalent_chromium_508.pdf.

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting chromium as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

To reduce your exposure to hexavalent chromium on a personal level, make sure to properly use personal protective equipment. Workers who may operate with hexavalent chromium are recommended to wear indicated personal protective equipment (PPE).[50]

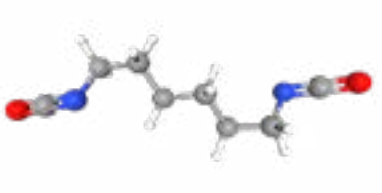
Since chromium is a component of tobacco smoke, quitting smoking or avoiding smoking indoors would limit exposure. Older, pressure-treated lumber may be treated with chromated copper arsenate. Try to avoid burning, cutting, or sanding these materials. Children should avoid playing in soil near hazardous waste sites where hexavalent chromium may have been disposed of. Lastly, clothing or items removed from the workplace might carry chromium if you work somewhere with high chromium exposure. Make sure to wash these after use.[46]

50 CDC - Niosh Pocket Guide to Chemical Hazards - Chromium (VI). https://www.cdc.gov/niosh/npg/npgd0138.html

Hexamethylene Diisocyanate (HDI)

What is it?

HDI is the common name for hexamethylene diisocyanate [hek-*suh*-**meth**-*uh*-leen dahy-**ahy**-soh **sahy**-*uh*-neyt], which is known in industry as Mondur HX and Desmodur H.[51] HDI is a pale-yellow liquid with a sharp, irritating odor.[52] Over 99% of the HDI used in the U.S. is used as hardeners in automobile and airplane paints. The remaining 1% is sold as rocket fuel binder and paint thickener.[51]

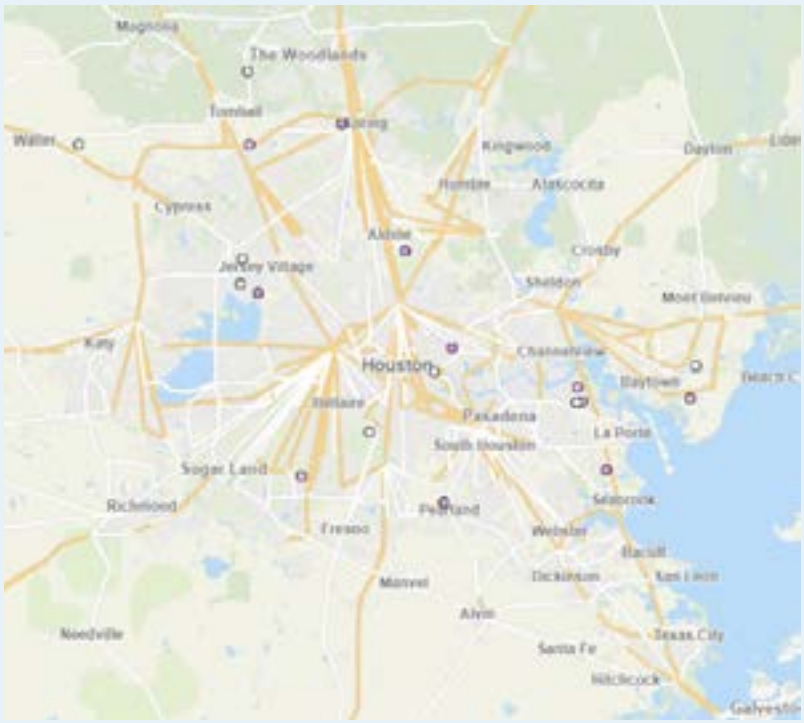


Emission sources

HDI is industrially produced through the controlled reaction of phosgene with amine salts.

HDI is usually found in the air near locations where spray paints that contain HDI are used, such as industrial coating and auto body shops. However, HDI breaks down quickly in both the air and water, so it is unlikely to build up in the environment. As a result, the general population is exposed to HDI when spray-painting a car with an HDI hardener or drinking contaminated tap water. People can also be environmentally exposed if they live near a hazardous waste site where HDI is disposed of.[35]

According to the EPA's NEI, the Houston area emitted approximately 670 pounds of HDI in 2017, entirely sourced from industrial surface coating and solvent use.[4]



Map of diisocyanate (including HDI) emitting TRI facilities in Houston (2020)

Health effects

Acute (short-term) health effects may occur immediately or soon after HDI exposure.

RESPIRATORY AND INTEGUMENTARY SYSTEM:

- Contact with HDI can severely irritate and burn the skin, eyes, nose, and throat.

51 Abadin, Henry, and Wayne Spoo. "Toxicological profile for hexamethylene diisocyanate." (1998).
52 New Jersey Department of Health. 2009. "Hazardous Substances Fact Sheet - Hexamethylene Diisocyanate." Official Site of the State of New Jersey. https://nj.gov/health/eoh/rtkweb/documents/fs/0995.pdf.

- Inhaling HDI can irritate the lungs, causing coughing, shortness of breath, and labored breathing.
- High exposures can cause serious respiratory issues like pulmonary edema, which is a build-up of fluid in the lungs.[52]
- Research shows that long-term exposure to HDI may cause chronic lung problems.[51] [52] [53]
- Animal studies also show that long-term exposure to HDI may have effects on nasal tissue, the respiratory tract, and the lungs.[51] However, it is not confirmed that these effects will be the same in humans.

NERVOUS SYSTEM:

Exposure to HDI can cause headache, dizziness, nausea, and vomiting.

IS THIS A CARCINOGEN?

There are currently no existing research studies on the carcinogenicity of HDI in humans. Thus the IARC, EPA, and DHHS have not produced a classification of HDI as a carcinogen or not.[54]

Who is at risk?

Individuals who have the greatest exposure to HDI are those who work in an industry or business in which HDI is used. During the paint hardener spraying process, small droplets of HDI in the air are breathed in by or lands on the skin of exposed workers.[51]

What can you do?

Find and contact your elected officials and ask for stricter emissions, engineering, and safety controls on facilities handling, processing, and emitting HDI as well as expanded local monitoring to ensure surrounding communities are not exposed to high concentrations.

To reduce your exposure to HDI on a personal level, make sure to properly use personal protective equipment. It is important to wear gloves and clothing that HDI will not permeate. Workers who may operate with hexavalent chromium are recommended to wear indicated personal protective equipment (PPE).[55]

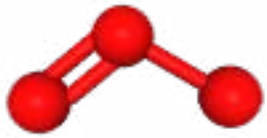
Safety equipment suppliers and manufacturers can give recommendations on the most protective glove and clothing material for your HDI use. To protect your eyes, wear indirect-vent, impact, and splash-resistant goggles when working with liquids. If needed, use respiratory protection to prevent inhalation exposures.[52]

53 United States National Library of Medicine. 2021. "Hexamethylene diisocyanate." National Center for Biotechnology Information. https://pubchem.ncbi.nlm.nih.gov/compound/Hexamethylene-diisocyanate.
54 Agency for Toxic Substances and Disease Registry (ATSDR). 2014. "ToxFAQs for Hexamethylene Diisocyanate (HDI)" Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service. https://wwwn.cdc.gov/TSP/ToxFAQs/ToxFAQsDetails.aspx?faqid=873&toxid=170
55 CDC - Niosh Pocket Guide to Chemical Hazards - Hexamethylene Diisocyanate. https://www.cdc.gov/niosh/npg/npgd0320.html

Ozone (O_3)

What is it?

Ozone [**oh**-zohn] is an odorless, colorless gas composed of three oxygen atoms.[56] [57] Depending on where these ozone molecules are located in the atmosphere, they can be helpful or harmful to human health.[56] If ozone exists in the atmosphere 10-30 miles above the Earth's surface – the stratosphere – it is beneficial and blocks harmful ultraviolet light from damaging our skin. However, if ozone exists at ground level – tropospheric ozone – it promotes photochemical smog formation and could lead to adverse health effects.[57] [58]



Emission sources

Ground-level ozone is not a directly emitted pollutant but is a byproduct of chemical reactions between nitrogen oxides (NOx) and VOCs in heat and sunlight. NOx and VOCs are primarily emitted by cars, power plants, industrial boilers, refineries, and chemical plants. VOCs may also be released from gasoline, solvents, paints, and other household chemicals.[57] For this reason, levels of ground-level ozone tend to be the highest near urban centers.

Health effects

Ozone in the air we breathe can harm our health, especially on hot sunny days when ozone can reach unhealthy levels. Even relatively low levels of ozone can cause health effects.

RESPIRATORY SYSTEM:

- Short-term ozone exposure can cause respiratory system irritation, coughing, throat inflammation and chest tightness.[57]
- Ozone may also reduce lung function, resulting in difficulty breathing deeply or vigorously which can induce more aggravated and frequent asthma attacks over the long term.
- Ozone can also increase susceptibility to lung infection and worsen chronic lung diseases like emphysema and bronchitis.
- Ozone can inflame and damage cells in your lung lining. After a few days, the damaged cells are shed and are replaced with new cells. However, if this damage happens repeatedly, the lungs

56 United States Environmental Protection Agency. 2018. "Actions You Can Take to Reduce Air Pollution." United States Environmental Protection Agency. https://www3.epa.gov/region1/airquality/reducepollution.html.
57 Chen, Tze-Ming, Ware G. Kuschner, Janaki Gokhale, and Scott Shofer. "Outdoor air pollution: nitrogen dioxide, sulfur dioxide, and carbon monoxide health effects." *The American journal of the medical sciences* 333, no. 4 (2007): 249-256.
58 Gad, Shayne C. "Ozone In: Encyclopedia of Toxicology: Third Edition." (2014): 747-750.

may experience longer-term impacts.[56]

- Long-term exposure to ozone is linked to aggravation of asthma, and is likely to be one of many causes of asthma development. Studies in locations with elevated concentrations also report associations of ozone with deaths from respiratory causes.[59]

IS THIS A CARCINOGEN?

Existing research does not point towards ozone being a human carcinogen, however, studies examining this are sparse and outdated.

Who is at risk?

The people who are most at risk from elevated ozone levels are:

- People with asthma
- Outdoor workers
- Children
- Older adults
- People with heightened sensitivity to ozone. For example, individuals with certain genetic characteristics or those with reduced intake of certain nutrients like Vitamin C and E.[56 59]

Children are at greatest risk from exposure to ozone because their lungs are still developing and they are more likely to be active outdoors when ozone levels are high, which increases their exposure.

What can you do?

The best way to protect your health is finding out when ozone levels are high in your area and minimizing potential exposure. The EPA and local air agencies have resources (like AirNow, EnviroFlash and TCEQ Ozone Action Day alerts) that provide updated information, reports, and alerts on current ozone levels and suggested actions to reduce your exposure. The Air Quality Index (AQI) reports current levels of ozone and other common air pollutants. The color scheme can help you determine if local air quality may adversely impact your health. For example, orange means that conditions are "unhealthy for sensitive groups," so a member of a sensitive group may want to reduce outdoor exercise. Purple indicates "very unhealthy" air quality, meaning that everyone should avoid outdoor activity.[57]

59 United States Environmental Protection Agency. 2021. "Health Effects of Ozone Pollution." United States Environmental Protection Agency. https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

The U.S. Environmental Protection Agency's Air Quality Index (AQI) for Ozone and Particle Pollution.[60]

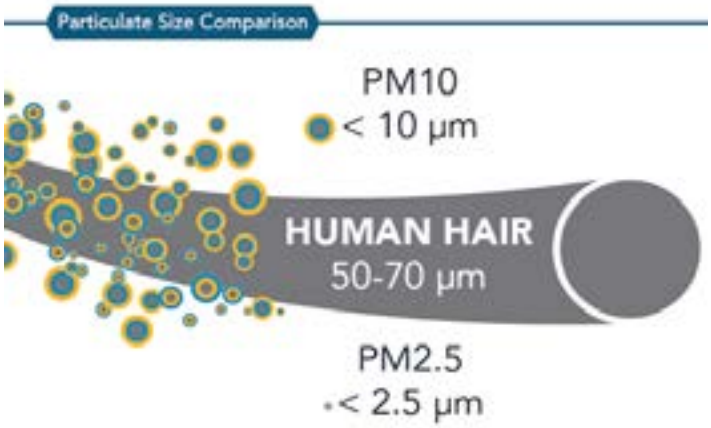
There are a few things you can do to reduce ozone levels personally. On days when high ozone levels are expected, choose a cleaner commute (carpooling or public transit), avoid idling your vehicle, and reduce energy consumption if possible.[52] Also, contact your elected officials and ask for stricter controls on industrial and mobile source emissions of ozone precursors as well as expanded monitoring to improve awareness.

60 AirNow, Air Quality Index (AQI) Basics. https://www.airnow.gov/aqi/aqi-basics/

Particulate Matter

What is it?

Particulate matter (PM) [per-**tik**-y*uh*-lit **mat**-er], also called particle pollution, is a mixture of solid particles and liquid droplets suspended in the air. Larger particles with diameters of 10 micrometers and smaller, known as "Coarse PM" or "PM10," can be seen by the eye. Others, known as "Fine PM" or PM2.5," have diameters of 2.5 micrometers and smaller, about 1/30th the width of a human hair, and can only be detected with a microscope.[61]



SOURCE: California Air Resources Board

Emission sources

Most PM pollution forms in the atmosphere as a result of complex reactions of chemicals emitted from power plants, industrial operations, as well as cars and trucks (e.g. sulfur dioxide and nitrogen oxides). They may also be emitted directly from construction sites, concrete batch plants, unpaved roads, fields, smokestacks, or fires.[59] It is worth noting that PM does not always get created locally but can travel long distances, even across continents, as is the case with airborne desert dust.[62]

In indoor settings, cooking, smoking, dusting, and vacuuming can also create PM pollution.[59]

Health effects

RESPIRATORY AND INTEGUMENTARY SYSTEM:

- When breathed in, particulate matter, especially fine particles, can penetrate deep into the lungs and enter the bloodstream.
- Exposure can trigger serious health conditions, including reduced lung development in children, higher rates of asthma, bronchitis, heart disease, cancer, and early death.[63]

61 United States Environmental Protection Agency. 2021. "Particulate Matter (PM) Basics." Epa.gov. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.
62 Neophytou, A., Yiallouros, P., Coull, B. et al. Particulate matter concentrations during desert dust outbreaks and daily mortality in Nicosia, Cyprus. J Expo Sci Environ Epidemiol 23, 275–280 (2013). https://doi.org/10.1038/jes.2013.10.
63 United States Environmental Protection Agency. 2021. "Health and Environmental Effects of Particulate Matter (PM)." epa.gov. https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm.

- Short-term effects even in healthy individuals may include eye and throat irritation, shortness of breath, headaches, dizziness, and nausea even in healthy individuals.[64]
- Early research also indicates a link between exposure to particle pollution and the risk of death from the novel coronavirus.[65]

IS THIS A CARCINOGEN?

In 2013, the IARC classified PM as carcinogenic to human beings. Reviews of the latest scientific literature by IARC have shown an especially high correlation between PM exposure and lung cancer.[66]

Who is at risk?

People who live, work, or attend school near industrial operations or busy roads have an elevated risk of exposure to PM, as concentrations are especially high near these sources. However, as PM can be carried over long distances by wind, it knows no boundaries, and neighborhoods miles from the original pollution source can experience high levels, too.

People with heart or lung diseases are at increased risk from PM because particles can aggravate these diseases. In addition, children whose lungs are still developing as well as older adults with potential health conditions are also at increased risk, especially when they are physically active, as physical activity causes faster and deeper breathing, drawing more particles into the lungs.[67] Pregnant people are another risk group as exposure to high particle levels is associated with adverse impacts on fetal development and children's long-term health.[68]

What can you do?

To reduce your exposure to outdoor particle pollution, use the EPA's daily Air Quality Index at AirNow.gov to check air quality and plan your outdoor activities accordingly. In addition, you can use the PurpleAir network map to check real-time PM levels near you.

- On days when the AQI forecast is unhealthy, reschedule, shorten or choose less-strenuous outdoor activities. Wearing a tight-fitting mask (such as an N95) also helps minimize inhalation of PM.[69]
- You can sign up to receive air quality alerts to be informed about days when the EPA's Air Quality Index scale for ozone and PM is forecast to reach harmful levels.

As higher levels of particle pollution tend to be found near busy roads and idling vehicles, spend less time outside near heavily traveled roadways, especially during rush hour, to minimize exposure.[70]

64 United States Forest Service. n.d. "Air Pollution Health Impacts." fs.fed.us. https://www.fs.fed.us/air/health_impacts.htm.
65 Friedman, Lisa. 2020. "New Research Links Air Pollution to Higher Coronavirus Death Rates." The New York Times, April 7, 2020. https://www.nytimes.com/2020/04/07/climate/air-pollution-coronavirus-covid.html?action=click&module=Top%20Stories&pgtype=Homepage.
66 World Health Organization (WHO). 2013. "Outdoor air pollution a leading environmental cause of cancer deaths." https://www.euro.who.int/en/health-topics/environment-and-health/urban-health/news/news/2013/10/outdoor-air-pollution-a-leading-environmental-cause-of-cancer-deaths.
67 United States Environmental Protection Agency. 2003. "Particle Pollution and Your Health." airnow.gov. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1001EX6.txt.
68 Johnson, Natalie M., Aline Rodrigues Hoffmann, Jonathan C. Behlen, Carmen Lau, Drew Pendleton, Navada Harvey, Ross Shore et al. "Air pollution and children's health—a review of adverse effects associated with prenatal exposure from fine to ultrafine particulate matter." *Environmental health and preventive medicine* 26, no. 1 (2021): 1-29.
69 CDC - NIOSH Approved Particulate Filtering Facepiece Respirators. https://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/default.html
70 United States Environmental Protection Agency. 2015. "Air Quality Guide for Particle Pollution." https://www.airnow.gov/. https://www.airnow.gov/sites/default/files/2021-03/air-quality-guide_pm_2015_0.pdf.

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The U.S. Environmental Protection Agency's Air Quality Index (AQI) for Ozone and Particle Pollution.[71]

To reduce your indoor particle pollution exposure, eliminate tobacco smoke, reduce your use of wood stoves and fireplace, use HEPA air filters and air cleaners designed to reduce particles, and avoid burning candles.

You can also take simple steps to help reduce PM pollution in your community. Because cars and other vehicles are big sources of this pollution, driving less, using public transit or biking and walking are great ways to reduce PM. If you must drive, keep your car engine tuned to reduce emissions. Other ways to help are to choose ENERGY STAR appliances when possible and to set thermostats higher in summer and lower in winter in order to reduce energy consumption, and therefore air pollution. Finally, avoid burning leaves, garbage, plastic, or rubber as that releases particulate matter into the air.

Finally, make sure to urge your elected officials to address the sources of particulate matter pollution and prioritize clean energy as well as to expand air monitoring to improve awareness.

71 AirNow, Air Quality Index (AQI) Basics. https://www.airnow.gov/aqi/aqi-basics/