Workplace Health and Safety
Bulletin
WORK SAFE ALBERTA

Benzene at the Work Site

Benzene is a flammable liquid made from hydrocarbons or coal. Before the First World War, benzene was used mostly as a solvent or in gasoline to enhance the octane number. Today, benzene is used mostly as a raw material to manufacture:

- ethyl benzene used to make styrene, an important ingredient in plastics and synthetic rubber,
- cumene used to make phenol which is an ingredient in adhesives and dyes,
- cyclohexane used to make nylon,
- chlorobenzenes used in pesticides,
- alkybenzene used in detergents, and
- aniline used in dyes and plastics.

Crude oil and natural gas condensate contain benzene although the concentration varies considerably depending on the geology and location of the well site. Drilling fluids may contain benzene and can also become contaminated with benzene when they are recirculated down well. Benzene and other hydrocarbons may be released from stacks, flares, hydrocarbon storage facilities, glycol dehydrators and other operations that involve crude oil or fuels. In the upstream oil and gas sector, glycol dehydrators are the primary source of benzene emissions. Improved industry practices have resulted in reduction of these emissions by 76% from 1995 levels.

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A small amount of benzene, usually less than 1 percent by weight, is still present in gasoline sold in North America. Workers may be exposed to benzene when gasoline is used or handled or from vehicle exhaust. The chemical is still used as a solvent and reagent in laboratories. Benzene is also a compound found in cigarette smoke.

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Synonyms for benzene include benzol, carbon oil, coal naphtha, cyclohexatriene and phenyl hydride.

Benzene is a clear, colourless liquid with a sweet odour. The odour threshold of benzene is around 60 parts per million (ppm), although there is a sizeable range in the reported values (0.78 to 160 ppm). Benzene is extremely flammable. Its flash point (the temperature where an ignition source can ignite benzene vapours) is -11^0 C. Its flammable range (concentration of vapours in the air) is from 1.2 to 7.8 percent. The vapour is heavier than air, so it can spread long distances and ignite far from the source and flashback. The liquid is lighter than water and it floats on top of water if mixed. Mixing or contact with strong oxidizers , for example peroxides, chlorine, ozone, nitric acid, perchlorates, can cause spontaneous combustion and, in some cases, explosions.

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Health effects

Acute health effects

Workers are usually exposed to benzene by inhaling the airborne vapours or by skin contact with the liquid chemical. The vapours in air can also be absorbed through the skin. This occurs to a much lesser extent than by direct contact with the liquid, and is unlikely to be a significant route of exposure when benzene concentrations in the air are less than 25 ppm.

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Short-term (acute) exposure to benzene at high concentrations can cause depression of the central nervous system, causing drowsiness, dizziness, headache, nausea, vomiting, sleepiness, fatigue, slurred speech, loss of balance and disorientation. These effects are not usual at concentrations below 25 ppm, and are more common at 50 to 150 ppm. As concentrations of benzene vapours in the air increase, the health effects become more severe (vertigo, confusion, loss of consciousness). Exposure to about 20,000 ppm for 5 to 10 minutes can cause death.

Nose and throat irritation have also been reported after short-term exposure.

Chronic health effects

Prolonged or repeated contact with the skin causes redness, drying, and cracking because benzene dissolves and removes the protective natural oils from the skin.

The most important health effect of benzene is its impact on the blood system. Benzene can be metabolized in the liver and bone marrow and its metabolites can damage the bone marrow where new blood cells are produced. At high concentrations these metabolites can cause a serious condition where the number of red blood cells, white blood cells and clotting cells is reduced (pancytopenia). In the initial stages, this effect is thought to be reversible, but with continued exposure it may progress to aplastic anemia (a rare blood disorder that results from the failure of the bone marrow to produce blood cells) or leukemia (a cancer that starts in blood cells). Benzene can weaken the immune system by lowering the number of white blood cells that are produced. Studies of workers have shown that the damage to the blood system can occur with exposure to benzene at concentrations of 30 ppm to 120 ppm over a time period of 3 months to 17 years. Exposure to benzene below workplace occupational limits have not been shown to produce damage to blood cells.

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The International Agency for Research on Cancer (IARC) has concluded that benzene is carcinogenic to humans. Benzene is classified as a Group 1 carcinogen. Long-term exposure to benzene may increase the incidence of a specific type of leukemia (acute myelogenous leukemia) and may (although the results are not consistent) be associated with other forms of leukemia and lymphomas **(**cancers that develop from cells in the lymphatic system).

Studies have shown that benzene can cross the placenta, but there is no conclusive evidence that it affects the fetus. Benzene can cause mutation of cells, usually when there is exposure to concentrations that are high enough to also cause blood changes.

Exposure to ethanol and benzene together can increase the effects to the blood system. Exposure to toluene and benzene can reduce the body's ability to remove benzene since the two chemicals are metabolized in a similar way.

Health Assessment

There is no regulatory requirement for workers exposed to benzene to have a health assessment, although it can be included as part of a worker surveillance program.

Biological Monitoring

The American Conference of Governmental Industrial Hygienists (ACGIH) has adopted Biological Exposure Indices (BEIs) for benzene. BEIs represent levels of metabolites that may be seen in samples from healthy workers who have been exposed at the Threshold Limit Value (TLV). BEIs reflect the absorption of a substance into the body from all routes and sources of exposure. The use of biological indices is not a substitute for workplace air monitoring.

The BEIs for benzene are:

S-Phenylmercapturic acid in urine (measured at end of shift)	25 µg/g creatinine
T,t-Muconic acid in urine (measured at end of shift)	500 µg/g creatinine

The ACGIH BEIs for benzene are based on an 8-hour exposure limit (TWA) of 0.5 ppm. In other words, exposure to benzene at a TLV of 0.5 ppm would result in levels of S-Phenylmercapturic acid or t,t-Muconic acid in the urine at the levels shown above. (Note that the Alberta Occupational Exposure Limit (OEL) for benzene is 1 ppm, so the ACGIH BEI for benzene cannot be used to relate back to worker exposure at the Alberta OEL.)

Note that heavy smokers (more than one pack per day) may already have these benzene metabolites in their urine above background levels since benzene is present in cigarette smoke.

Preventative Measures

Preventing exposure to benzene is the best way to protect health. Options that should be considered include the following (listed in order of preference):

- use of less hazardous substitutes
- use of engineering controls
- changes in work practices to reduce exposure (administrative controls)
- use of personal protective equipment

Substitution

One option to control exposure to benzene is to use other solvents when practicable. For example, some alcohols and cyclohexane can be substituted for benzene as a solvent in laboratory procedures. Toluene, which has a similar chemical structure to benzene, is also often used as a substitute. However, substitution may not always be possible when benzene is the raw material for the manufacture of another product. In addition, the substitutes may have their own health hazards.

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Engineering Controls

Engineering controls are processes used to eliminate exposure to a substance. Engineering controls remove the substance from the air or provide a barrier between the worker and the substance. Examples of engineering controls that can be used to prevent exposure to benzene include:

- installation of local ventilation hoods
- enclosures around work processes (fume hoods, glove boxes)
- use of automatic systems to pump benzene or substances containing benzene from storage containers to process containers

Fuels that contain benzene must be handled carefully. Even though they contain only a small amount of benzene, enough benzene vapours can be released during product handling to exceed occupational exposure limits.

Where ventilation systems are used at the work site, they must be properly designed and not vent back into the work area. For example, benzene emissions from glycol dehydrators can be reduced by installing flash tank separators. Environmental standards may also restrict the amount of benzene that can be discharged to the outside air.

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If engineering controls are working properly, they will eliminate or greatly reduce the potential hazard. They only need to be installed once and do not place a physical burden on workers. However, an initial investment is required and the systems must be properly operated and maintained once installed.

Administrative Controls

Work practices that can be used in the workplace to reduce exposure to benzene include:

- educating workers about the hazards of benzene. Workers must participate in training and monitoring programs in the workplace.
- using good hygiene practices. Workers must not eat, drink or use tobacco products in areas where benzene or products containing benzene are used or stored. The hands and face should be washed before eating, drinking or smoking.
- using and maintaining engineering controls and other equipment used to reduce exposure properly.
- storing benzene properly.
- ensuring that unprotected workers are not in areas where products containing benzene are used.
- the clean up of spills quickly and properly, using appropriate protective equipment and clothing.
- keeping product containers tightly sealed when they are not in use.

When benzene or a product containing benzene is used in the workplace, air monitoring should be done periodically to ensure that the OEL is not exceeded. Air samples must be collected and analyzed using a National Institute of Occupational Safety and Health (NIOSH) method or a method approved by a Director of Occupational Hygiene. NIOSH has four methods that can be used for benzene:

(1) 11500, Hydrocarbons 36-126 ^{o}C BP
(2) 1501, Hydrocarbons, Aromatic
(3) 2549, Volatile Organic Compounds (Screening)
(4) 3700, Benzene by Portable GC

The method selected depends on the workplace conditions and the range and precision needed. Only individuals who have the appropriate training and experience should take the measurements. NIOSH methods are available online at

www.cdc.gov/niosh/nmam/

Benzene presents a fire hazard as well as a health hazard to workers. Many of the products that contain benzene (e.g. gasoline) are also themselves flammable. Particular attention must be paid to fire safety and potential sources of ignition in areas where benzene is used and stored. Benzene should be stored in a cool, dry, well-ventilated area, out of direct sunlight and in a part of the work site that is separate from the production area. Benzene should never be stored with oxidizing chemicals.

Implementing work practices to reduce exposure are often less expensive than other control measures, but workers must be properly trained and use the safe work practices. The employer must monitor this in the workplace.

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Personal Protective Equipment

If it is not practicable or feasible to use substitutes, engineering controls or administrative controls to reduce the potential for exposure, or they are not sufficient, the employer must provide workers with appropriate protective equipment.

Respiratory protective equipment is needed to protect workers from inhaling airborne vapours. There are many types of respirators available. It is important to select the correct level of respiratory protection based on the type of work being done and the airborne concentrations of benzene at the work site.

Properly operating air-supplying respirators are usually the most effective type of respiratory protection for benzene vapours. Air purifying respirators with organic vapour cartridges may not provide enough protection against benzene exposure. The concentration of benzene detectable by most people by smell is higher than the OEL. Because of this, the wearer will not be able to detect when a cartridge is in need of changing and may unknowingly become overexposed.

If air-purifying respirators are used for benzene, the employer must:

- ensure that the respirator has an end-of-use indicator (the indicator will show when the cartridges must be changed), or
- use a change-out schedule that has been calculated by a competent person. If a calculated change-out schedule is used, the U.S. Occupational Safety and Health Administration (OSHA) method, or an equivalent method, must be used. The employer must also have written procedures that address how the calculations are done, confirm the method used for the calculations and specify training to ensure that workers understand and use the system for cartridge change out. The OSHA method may be accessed online at

  www.osha.gov/SLTC/etools/respiratory/change_schedule.html

For more information

Alberta Human Resources and Employment has the following publications available on respiratory protective equipment:

www.hre.gov.ab.ca/documents/WHS/WHS-PUB_ppe004.pdf
Guideline for the Development of a Code of Practice for Respiratory Protective Equipment

www.hre.gov.ab.ca/documents/WHS/WHS-PUB_ppe001.pdf
Respiratory Protective Equipment: An Employer's Guide

www.hre.gov.ab.ca/documents/WHS/WHS-PUB_mg005.pdf
Medical Assessment of Fitness to Wear a Respirator

Employers should also refer to the CSA Standard Z94.4-02, *Selection, Use and Care of Respirators.*

Since benzene and benzene vapours can be absorbed through the skin, solvent resistant gloves and other protective clothing are needed for workers who handle the chemical or may be exposed to airborne vapours. Different protective clothing and glove materials will be needed depending on whether the worker will be exposed to pure benzene, or benzene as a component in a mixture (e.g. gasoline). For mixtures containing benzene, choose a material that has been tested for similar mixtures. For example, a material with resistance to gasoline will provide protection for condensate and crude oil as well.

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Information about protective clothing materials recommended for benzene is available from NIOSH database "Recommendations for Chemical Protective Clothing". The database is available online at

www.cdc.gov/niosh/ncpc/ncpc2.html.

Workers who may be exposed to benzene should ensure that they wear protective clothing that covers and protects the arms and legs. Close fitting goggles or full-face respirator masks should be worn to protect the eyes from irritation or splashes. Where skin contact with liquids containing benzene occurs, the area should be thoroughly washed immediately.

Although the use of personal protective equipment may initially seem less costly, workers need to be trained to use, care for and maintain the protective equipment they use. Employers need to monitor use and ensure that the protective equipment is properly maintained. In some cases, personal protective equipment can create a hazard to workers (heat stress, limited vision, allergic reactions to the equipment material). These issues need to be evaluated when personal protective equipment is selected.

Regulatory Requirements

The health and safety legislation has general and specific requirements related to benzene. An OEL for benzene is provided. This limit applies to workers directly involved with tasks using benzene or products containing benzene, and also to other workers in the workplace who may be exposed to benzene indirectly from these operations. It is important to note that OELs represent standards for the protection of the most healthy workers. Steps must be taken to keep benzene levels as low as reasonably practicable.

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The employer must also:

- develop a Code of Practice for benzene if there is more than 10 kg of the pure chemical or a mixture that contains more than 0.1% by weight and the total amount of benzene in the mixture exceeds 10 kg,
- train workers on the health hazards from exposure to benzene and the safe work procedures developed by the employer,
- comply with requirements for handling and storage of flammable materials,

- ensure that the need for ventilation is properly assessed and systems that are installed are properly designed and maintained. Workers also need to be trained on the proper operation and maintenance of these systems.
- provide appropriate protective equipment (including respirators) where concentrations of benzene cannot be controlled below safe limits. Workers must use the required protective equipment and must be trained on its proper use and care.

Additional requirements for the handling and storage of flammable materials in the workplace are in Part 4 of the Alberta Fire Code. More information on these requirements can be found on the Alberta Municipal Affairs website at

 www.municipalaffairs.gov.ab.ca/ss/Fire.cfm.

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