World Health Organization

PREVENTING DISEASE THROUGH HEALTHY ENVIRONMENTS

EXPOSURE TO BENZENE: A MAJOR PUBLIC HEALTH CONCERN

Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and haematological effects. Exposure can occur occupationally, in the general environment and in the home as a result of the ubiquitous use of benzene-containing petroleum products, including motor fuels and solvents. Active and passive exposure to tobacco smoke is also a significant source of exposure. Benzene is highly volatile, and exposure occurs mostly through inhalation.[1,2] Public health actions are needed to reduce the exposure of both workers and the general population to benzene.

Sources of exposure to benzene

Benzene is highly volatile, and most exposure is through inhalation. Benzene is degraded rapidly in the upper atmosphere. Because of its solubility in water, a minor amount may be removed by rain and contaminate surface waters and soil. However, it is not persistent in surface water or soil and is either volatilised back to air or degraded by bacteria.

Industrial processes[1-3]

As benzene occurs naturally in crude petroleum at levels up to 4 g/L, human activities using petroleum lead to exposure. These activities include processing of petroleum products; coking of coal; production of styrene, phenol, cyclohexane, ethylbenzene, cumene and other aromatic compounds; and use in industrial and consumer products, as a chemical intermediate and as a component of petrol (gasoline) and heating oils. The presence of benzene in petrol and as a widely used industrial solvent can result in significant occupational exposure, although the concentration of benzene in gasoline has been limited in some jurisdictions and its use as a solvent is now restricted in many countries. However, exposure to benzene was noted to still occur in industries where high levels were observed historically, such as shoemaking, painting, printing and rubber manufacturing.[3] These extensive industrial uses also result in widespread emissions to the environment. The main sources of benzene in the environment include automobile exhaust, industrial sources, and fuel evaporation from gasoline filling stations.[1] Off-gassing from building materials and structural fires lead to increased atmospheric benzene levels. Industrial discharge, landfill leachate and disposal of benzene-containing waste are also sources of exposure.

Indoor residential air[1,2]

Benzene has been detected at high levels in indoor air. Although some of this exposure might be from building materials (paints, adhesives, etc.), most is from cigarette smoke in both homes and public spaces. Levels of benzene are higher in homes with attached garages than in those with detached garages. Levels are increased in homes close to petrol filling stations and in areas with heavy traffic. Benzene may be released to residential indoor air from unvented oil heating, from the use of benzene-containing consumer products, and from

leaking underground gasoline storage tanks. People who spend more time indoors – such as children – are likely to have higher exposure to benzene.

Inside vehicles

Benzene has been measured in air inside vehicles at levels higher than those in residential air, but substantially lower than those at petrol filling stations.[4]

Food and water

Waterborne and foodborne benzene contributes only a small percentage of the total daily intake in non-smoking adults.[1,2]

World Health Organization (WHO) benzene guidelines

Drinking-water

The guideline value for benzene is 0.01 mg/L (based on extrapolation of modelled excess lifetime risk for leukaemia from epidemiological studies involving inhalation exposure; guideline values corresponding to modelled excess lifetime cancer risks* of 10^{-4}, 10^{-5} and 10^{-6} are 0.1, 0.01 and 0.001 mg/L, respectively).[5,6] Similar excess cancer risk estimates were derived from a two-year gavage study in rats and mice (i.e. risks of 10^{-4}, 10^{-5} and 10^{-6}, associated with drinking-water concentration ranges of 0.1–0.8, 0.01–0.08 and 0.001–0.008 mg/L, respectively).

Air

No specific guideline value has been developed for benzene in air. Benzene is carcinogenic to humans and no safe level of exposure can be recommended. For general guidance, the concentrations of airborne benzene associated with an excess lifetime risk of leukaemia of 10^{-4}, 10^{-5} and 10^{-6} are 17, 1.7 and 0.17 $\mu g/m^3$, respectively.[4]

Health effects

Acute effects

- Acute occupational exposure to benzene may cause narcosis: headache, dizziness, drowsiness, confusion, tremors and loss of consciousness.[2] Use of alcohol enhances the toxic effect.[7]
- Benzene is irritating to the eyes, skin and respiratory tract.[7]

Effects following chronic exposure

- Benzene is a well-established cause of cancer in humans.[1,3] The International

*An excess lifetime cancer risk of 10^{-4}, 10^{-5} or 10^{-6} means the risk of one new cancer case above background levels per 10 000, 100 000 or 1 million people, respectively.

Agency for Research on Cancer (IARC) has classified benzene as *carcinogenic to humans* (Group 1).[1,3] The evidence in humans is considered sufficient for acute non-lymphocytic leukaemia, including acute myeloid leukaemia, while the evidence in humans is limited for non-Hodgkin lymphoma, chronic lymphoid leukaemia, multiple myeloma, chronic myeloid leukaemia, acute myeloid leukaemia in children, and lung cancer.[3,8] Benzene also caused a wide range of cancers in laboratory animals, including in the offspring of exposed females.[8]

- Benzene causes haematotoxicity and is immunosuppressive.[1,3] Chronic exposure to benzene can cause reduced production of both red and white blood cells from bone marrow in humans; higher exposures can lead to aplastic anaemia and pancytopenia.[2,3] Haematotoxicity induced by benzene exposure is associated with risk of developing haematological malignancy or related disorders.[3] Benzene consistently induced immunosuppressive effects on humoural and cell-mediated functional assays in experimental animals; however, effects on immune function in humans have not yet been studied.[3]
- Benzene is metabolically activated to electrophilic metabolites, induces oxidative stress, and is genotoxic, inducing DNA damage and chromosomal changes. Occupational exposure to benzene has been associated with a range of genotoxic effects, including oxidative DNA damage, DNA strand breaks, gene mutations, chromosomal aberrations and micronuclei.[3] DNA adducts, chromosomal aberrations, micronuclei, sister chromatid exchange and sperm head abnormalities have been seen in laboratory species treated in vivo.[1–3] DNA adducts, DNA damage and chromosomal aberrations were seen in human cells in vitro.[3]
- Benzene is fetotoxic in mice, rats and rabbits following maternal exposure by inhalation, causing a reduction in birth weight.[2] It is not, however, teratogenic in experimental animals, even at maternally toxic doses, although maternal exposure to benzene resulted in haematopoietic changes in offspring, which recurred when the offspring were re-exposed as adults.[2]

Monitoring exposure

- Estimates of recent benzene exposure can be made through measurement of urinary inorganic and organic sulfate conjugates, trans, trans-muconic acid and S-phenylmercapturic acid.[1,2] Urinary phenol levels have also been used to estimate benzene exposure, although this test is considered more limited.[2]
- The haematological effects of chronic benzene poisoning in exposed workers can be detected by monitoring blood counts at regular intervals. For example, the United States Occupational Safety and Health Administration (OSHA) recommends monthly blood counts and removal of workers from areas with high benzene exposure if they have a haemoglobin level or haematocrit below normal limit for the geographic area or a persistent downward trend, a platelet count more than 20% below the employee's most recent value or outside the normal limit, or a leukocyte count below 4000/mm.[3,9]

Risk mitigation recommendations

Eliminate use

- Promote the use of alternative solvents in industrial processes, glues and paints.
- Develop and implement policies and legislation to remove benzene from consumer products.

Reduce exposure

- Reduce exposure at petrol filling stations as far as possible by following best practices in location, design and extraction.
- Minimize emissions from vehicle exhausts by improved design and regular monitoring of engine settings.
- Separate dwelling spaces from areas where vehicles and benzene-containing products are kept. In particular, isolate children from indoor exposure to vehicle emissions.
- Avoid domestic use of benzene-containing products.
- Discourage indoor use of unflued oil and gasoline heating.
- Implement the WHO Framework Convention on Tobacco Control,[10] including providing for protection from exposure to tobacco smoke in indoor workplaces, public transport, indoor public places and, as appropriate, other public places.

Education

- Raise public awareness regarding sources of exposure to benzene – especially exposure through smoking – and awareness of risk mitigation measures.
- Conduct educational activities to discourage the use of benzene or petrol for cleaning and degreasing in industry, including in the informal sector.

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