Q&A on Public Health Impacts on Benzene Exposure: Technical Appendix

The following questions and answers (Q&A's) have been prepared to provide community information on benzene air exposures as highlighted in the Sarnia Area Environmental Health Project (SAEHP) and recent peaks of benzene levels.

Discussion of other exposures such as those for workers (e.g., occupational exposures) and accidental releases of concentrated benzene (e.g., chemical spills) are aimed at providing context around community exposures.

The following organizations have reviewed and provided comments on an earlier draft of this document: Public Health Ontario, Health Canada, Environment and Climate Change Canada, Ministry of Health, Ministry of Environment, Conservation and Parks, Ontario Health, Lambton Public Health, and representatives from Aamjiwnaang First Nation.

Q1. What is Benzene?

Benzene is a chemical that is a colourless liquid at room temperature with a sweet odour. Benzene evaporates quickly in air and belongs to a class of chemicals called volatile organic compounds (VOCs). Benzene is also considered a solvent, as it can dissolve other chemicals and is a by-product of petrochemical refining, as well as the key ingredient in the production of styrene.

References: ATSDR (2007)

Q2. How does Benzene get into the air?

Benzene is released into the environment mostly through industrial emissions. There are also natural sources of benzene including forest fires and volcanoes that may contribute low concentrations in oceans, groundwater, and air.

Most benzene is made from petroleum-based products and is widely used to make a variety of products including Styrofoam, plastics, and rubbers. It is also added in small quantities to gasoline to improve engine performance. Benzene is also formed and released into the air when any carbon-based material is burned, which includes fossil fuels such as coal, diesel, and gasoline.

References: ATSDR (2007), Health Canada (2009)

Q3. How are people exposed to Benzene?

Benzene rapidly evaporates in the environment and 99.9% of benzene ends up in the air. As a result, low levels of benzene are present in outdoor air and everyone is exposed to a small amount of benzene outdoors, in the home, and in the workplace. However, exposures may be higher for people who work with benzene or those who live in areas close to industrial emissions of benzene. In some areas near petrochemical and petroleum industries, like the area studied in the Sarnia Area Environmental Health Project, benzene levels are higher than other communities in Southwestern Ontario and measure highest when the winds are blowing from the directions of main industrial sources.

Benzene in indoor and outdoor air accounts for an estimated 98-99% of total exposure for most Canadian non-smokers. Cigarette smoke is a major source of benzene, therefore people who smoke or

live with smokers may be exposed to larger amounts of benzene. For example, cigarette smokers may have ten times the daily intake of benzene compared to non-smokers.

- Outdoor benzene concentrations vary across and within communities and over time depending on factors such as proximity to facilities that produce or use benzene, local weather, geography, other sources, and natural events such as forest fires. Studies conducted by Health Canada have found that median levels of benzene in outdoor air range from 0.2 to 2.2 $\mu g/m^3$ (the highest 5% ranged from 0.3 to 4.5 $\mu g/m^3$) across Canada, with higher levels typically observed in urban settings. Some communities associated with large industrial sources can have higher levels of benzene.
- The Clean Air Sarnia and Area (CASA) website provides data on ambient air monitors across Sarnia. In Aamjiwnaang, monitoring from 2019 to 2023 shows annual concentrations ranging between 3.3 $\mu g/m^3$ and 7.0 $\mu g/m^3$ at the Ada (Lockridge) Rogers Station by the Aamjiwnaang First Nation Band Office. Further south, the annual average concentrations ranged between 0.5 $\mu g/m^3$ and 1.5 $\mu g/m^3$ at the Errnol Gray Sr. station by the E'Mino Bmaad-Zijig Gamig Health Centre.
- In addition to elevated long-term exposures in these communities, intermittent high "peaks" in benzene concentration in air can also occur at varying frequencies.
- Based on the Ministry of the Environment, Conservation and Parks (MECP) data, between January 1st, 2019, and May 24th, 2024, the maximum benzene level measured over 1-hour was 372 $\mu g/m^3$ (in 2023) and the maximum over 24-hours was 84 $\mu g/m^3$ (in 2019).
- In most communities across Canada, indoor air generally contains higher levels of benzene compared to outdoor air. Studies conducted by Health Canada in homes and public spaces across Canada have found that median levels of benzene in indoor air range from 0.4 to 2.2 $\mu g/m^3$ (the highest 5% ranged from 2.4 to 18.6 $\mu g/m^3$). Benzene in indoor air can originate from many sources including building materials, furniture, paints, glues, other consumer products as well as infiltration from ambient air. Cars parked in attached garages can also be a major contributor to indoor benzene concentrations.
- People who work in certain industries or occupations may have significantly higher exposures than the general public. According to CAREX Canada, the most common occupational exposure settings for benzene in Canada include automotive repair and maintenance, taxi and limo services, printing, firefighting, and automobile dealers. Other industries include petrochemical and petroleum refining, rubber tire manufacturing, and transport/storage of benzene.
- Given how quickly benzene evaporates into the air, it is unlikely that benzene will deposit onto clothing or surfaces. Benzene can also be ingested from beverages and food, but these are considered minor sources for most people

References: Health Canada (2009), Health Canada (2023), Carex (2024), ATSDR (2007)

Q4. What are the levels of benzene found in Canadians?

The Canadian Health Measures Survey (CHMS) is a national survey led by Statistics Canada, in partnership with Health Canada and the Public Health Agency of Canada, that collects information about the general health of Canadians and includes measurements of chemicals in blood and urine samples. The objective of the chemical measurements in the CHMS survey is to establish baseline levels in the Canadian population, to assess changes in exposures over time, and to inform research and regulatory

activities. Data collected from 2012 to 2017 for the CHMS, found that the average levels of benzene measured in the blood of people in the Canadian population (aged 12 to 79) ranged from 0.12 – 0.14 µg/L for people who smoke cigarettes and 0.027 – 0.029 µg/L for people who do not smoke cigarettes.

References: Health Canada (2024)

Q5. What happens to benzene in the body?

When people breathe in benzene, about half of the inhaled benzene will enter the bloodstream through gas exchange in the lungs. Animal studies show most ingested benzene will be absorbed into the bloodstream through the lining of the gastrointestinal tract. Benzene is converted to other breakdown products (metabolites) in the liver and bone marrow, some of the harmful effects of benzene exposure may occur in these sites. Most of these metabolites are excreted in urine within 48 hours after exposure.

References: Virginia Department of Health (2018)

Q6. a. What are the health effects of exposure to benzene?

Potential health effects of benzene depend on how much a person was exposed to, how long a person was exposed, how often a person was exposed, the routes of exposure and other factors associated with the individual (such as age, health, genetics, lifestyle, and other chemicals the person is exposed to). These risk factors are further influenced by social and structural determinants of health, including social, economic, and environmental conditions.

In general, breathing in benzene has been found to have an adverse impact on the central nervous system, can cause respiratory irritation, and changes to blood cells and how the immune system functions. Benzene has also been classified as causing cancer to humans and is associated particularly with leukemia including acute myeloid leukemia. Individuals concerned about benzene exposure can contact their health care provider.

References: ATSDR (2007)

Q6. b. What are short-term (acute) health effects of exposure to benzene?

For most Canadians, 98-99% of exposure to benzene occurs through inhalation. Animal studies suggested that short-term exposure via inhalation may lead to changes in blood cell counts and effects on the immune system. Based on very high levels observed in animal and occupational studies, benzene inhalation can irritate the nose and throat and affect the nervous system. Symptoms may include headache, nausea, dizziness, drowsiness, and confusion. Occupational studies have found that workers breathing in high levels of benzene (~48,000 µg/m^3 to 192,000 µg/m^3) over hours can cause dizziness, headaches, drowsiness, confusion, rapid heart rate, and unconsciousness; at extreme concentrations for a few minutes (5-10 minutes at 32,000,000 µg/m^3) it is assumed to be potentially lethal. Occupational studies have shown that exposures to concentrations above 3,200 µg/m^3 can damage blood cells, bone marrow, and the immune system, leading to regulations that protect people in the workplace. These kinds of very high short-term exposures have been seen in some workplaces. More recent studies have also suggested potential effects below 3,200 µg/m^3 and this continues to be an area of developing knowledge.

For levels of benzene observed in the Sarnia area, see Question 3.

References: ATSDR (2007), Health Canada (2009), Health Canada (2024), Health Canada (2023)

Q6 c. What are the long-term health effects of exposure to benzene?

The World Health Organization's International Agency for Research on Cancer (IARC) has classified benzene as a carcinogen based on its association with leukemia including acute myeloid leukemia. IARC has also determined that there is limited evidence linking benzene exposure to other cancers in humans (lung cancer, chronic myeloid leukemia, chronic lymphocytic leukemia, non-Hodgkin lymphoma, and multiple myeloma). Long-term exposure to benzene is associated with an increased risk of developing cancer (leukemia) and can affect the development of blood diseases (e.g., aplastic anaemia) and reduced immune function.

It is generally accepted that any exposures to benzene (e.g., such as those found inside homes and in ambient air) are associated with some degree of cancer risk. Much of the human (epidemiological) evidence documenting benzene's carcinogenic effects comes from studies of workers who were exposed to benzene at high concentrations repeatedly over a long period of time. There is limited epidemiological information on associations with cancer for people living near industrial areas.

References: IARC (2018) and ATSDR (2007)

Q7 a. Are there any standards and benchmarks for benzene?

The Ministry of the Environment, Conservation and Parks (MECP) has set a number of standards and benchmarks to evaluate short-term and long-term air quality. They are set at levels which are protective against adverse health effects over different periods of time.

For contaminants that can cause cancer, like benzene, the MECP sets a level for long-term (annual) air quality at a concentration that would give a person, exposed over the long term, a one in a million chance of getting cancer over their lifetime. Exposures to benzene levels above these limits does not mean an adverse effect will occur, but risks of developing the adverse effects increase as the magnitude (how high), the duration (how long), and frequency (how many times) increases.

Benchmarks for evaluating air quality:

- 0.45 µg/m^3: for long-term (annual) average air concentrations
- 30 µg/m^3: for short-term (24-hour) average air concentration
- 90 µg/m^3: for short-term (1-hour) average air concentration

The MECP uses these levels to understand the health risks, track air quality, and manage emissions.

Q7 b. How much benzene can you be exposed to over the long term?

Benzene is a chemical that can cause cancer, so it is important to limit exposure as much as possible. Risks of developing cancer increases as the magnitude (how high), the duration (how long) and frequency (how many times) increases.

Based on the MECP's long term (annual) benchmark of 0.45 µg/m^3, the additional risk of cancer would be:

- One in 1,000,000 - if a person were to be exposed up to an average concentration of 0.45 µg/m^3 over their lifetime.

- One in 100,000 - if a person were exposed to up to an average concentration of 4.5 µg/m^3 over their lifetime.
- One in 10,000 - if a person were exposed to an average concentration of up to 45 µg/m^3 over their lifetime.

Q7 c. How much benzene can you be exposed to over the short term?

Benzene is a well-recognized carcinogen and therefore all exposures (both short-and long-term) should be minimized. The MECP has short-term air quality benchmarks for benzene in outdoor air, which are set well below the concentrations that would cause health effects in short-term exposures to for benzene. MECP short-term benchmarks are:

- 30 µg/m^3: for short-term (24-hour) average air concentration
- 90 µg/m^3: for short-term (1-hour) average air concentration

Exposures to benzene levels above these levels does not mean an adverse effect will occur, but risks of developing the adverse effects increase as the magnitude (how high), the duration (how long) and frequency (how many times) increases.

Q8. What are the effects of benzene exposure on pregnant people and fetuses?

Benzene may pass from the mother to the fetus. Benzene can cross the placental barrier and has been detected in umbilical cord blood. Benzene has been also detected in human breast milk. Information on benzene's effects on fetuses have come from experimental studies in which animals were exposed to very high levels of benzene. These studies have shown that the offspring of pregnant animals that were breathing benzene at levels greater than 150,150 µg/m^3 experienced decreased fetal weight and skeletal changes. Human studies are based on observations of pregnant people who work with benzene and are therefore exposed to higher levels of benzene than the general population (but much lower than levels in animal studies). The findings of these human studies have been inconclusive, as a result benzene concentrations associated with impacts for pregnant people has not yet been established based on human studies. More research is needed in this area.

References: ATSDR (2007)

Q9: Are children, pregnant women, and the elderly at higher risk of toxic effects from benzene?

Some people may be more susceptible to the health effects of benzene, including women, children, and pregnant individuals. Currently there is no evidence to suggest that benzene exposure affects people with active cancer or cancer in remission differently than people without cancer. Because benzene can affect bone marrow, it is thought that those with increased bone marrow activity (e.g., fetuses, infants, individuals with blood conditions) could be more susceptible to its effects on the blood, but there is currently no direct human evidence of this. Studies on animals show that pregnancy is a more vulnerable time for benzene exposure.

References: ATSDR (2007) and Health Canada (2023)

Q10. What should you do if someone is experiencing symptoms that could be associated with benzene exposure?

There are no specific treatments or testing used to medically manage benzene exposures, including at concentrations reported in the community. Health care providers can manage individual concerns and symptoms based on their clinical assessment.

If you have any symptoms that may be related to benzene exposure, it is important to speak with your health care provider. Please consult with your health care provider if you are experiencing symptoms that could be associated with exposures to benzene. If you are experiencing any new or worrisome symptoms, seek medical attention, regardless of known or suspected exposure.

Q11: How are acute benzene exposures treated (resources, consults)?

Health care providers should be aware that for acute benzene exposures (e.g., during spills), the mainstay of treatment is removal from exposure. No medical intervention or testing specific to benzene is required; supportive management should be provided. Individuals who are concerned about symptoms related to a potential exposure can speak with their health care provider.

Health care providers can consider the following:

- Acute (short-term) inhalation exposure of humans to benzene are non-specific and may cause drowsiness, dizziness, headaches, as well as nasal irritation and, at high levels, unconsciousness. Most of these effects have been studied in occupational health settings at around 48,000 µg/m^3 to 192,000 µg/m^3. Due to limited data in community settings with acute benzene exposure, clinicians may observe the health effects at lower benzene levels than those reported in occupational studies.
- For levels of benzene observed in the Sarnia area, see Question 3.
- The duration of symptoms after an acute exposure to benzene cannot be predicted as it depends on many factors such as characteristics of the exposure (e.g., concentration, duration, route), and characteristics of the individual (e.g., age, breathing rate, medical comorbidities). In general, non-specific neurological symptoms associated with benzene exposure should resolve within minutes to hours of removal of exposure, as benzene is metabolized quickly in the body (half-life of ~8 hours).
- Testing for benzene in the body is not widely available, and only indicates recent exposure levels (i.e., levels do not correlate with clinical symptoms or predict future illness). Chronic benzene exposure is associated with an increased risk for certain cancers and has been most consistently observed in occupational populations where exposure concentrations are much higher than typical community levels. Additional information on testing for benzene is available under Question 13.
- Persistent unexplained symptoms should be assessed for all potential causes.

In the event of an industrial accident or spill, individuals may be acutely overexposed with signs of toxicity. However, there is no antidote for benzene toxicity. The mainstay of management is supportive, with removal from exposure, removal of contaminated clothing, and decontamination of the individual (e.g., eye flushing for direct splash/spray exposure as indicated). Local emergency departments can manage these situations and the Ontario Poison Centre can provide clinical support.

References: ATSDR 2000, ATSDR (2007), and ATSDR (2015)

Q12. How can one reduce their exposure to benzene?

Benzene exposures from drinking water, food, and outdoor air cannot be effectively controlled by individuals. In addition, exposures through skin contact (i.e., dermal exposures) and ingesting food or water containing benzene, are more often associated with worker or occupational exposures, or food and water supplies contaminated by a sudden and accidental release of benzene (e.g., benzene released in a large fuel spill). These routes of exposure are addressed by regulations and standards which are set to reduce (or limit) health risks. As an example, benzene emissions in Ontario are regulated under the *Environmental Protection Act* by the Ministry of the Environment, Conservation and Parks (MECP). On a national level, benzene emissions are covered under various risk management regulations and measures developed under the under the *Canadian Environmental Protection Act*.

However, there are some things that individuals can do to reduce their exposure to benzene from cigarette smoke and gasoline as these can be important sources of exposure for some people.

- Avoid exposing other people, particularly children, to second-hand smoke in enclosed environments.
- If your home has an attached garage:
    - Make sure there is a tight seal between your home and garage, particularly for any door that connects the two.
    - Install an exhaust fan and avoid idling vehicles in an attached garage.
    - Where possible, remove solvents, gasoline and other fuels, and gasoline-powered tools and engines from attached garages; consider alternative storage locations not attached to or in the home.

Air cleaners with sorbent media such as charcoal air filters may be able to lower volatile organic compounds (VOC) levels indoors, but these devices have not been certified nor their have their performance or effectiveness for benzene removal been evaluated. High efficiency particulate air (HEPA) filters are mechanical fibrous filters that are effective at removing particulate matter; however, they will not remove benzene and other VOCs from the air.

References: ATSDR (2007), Health Canada (2009), US EPA (2018)

Q13. Is there a laboratory test for measuring benzene exposure in humans?

Health care providers should be aware that tests can measure benzene directly in the body or its breakdown products (e.g., blood, urine, or exhaled breath), however they may provide limited value for clinical management and should be interpreted with the following in mind:

- Benzene exposure is common in Canada (e.g., from cigarette smoke, gasoline, indoor furnishings), so most individuals will have detectable levels. Information on the levels of benzene found in Canadians can be found in Question 4.
- Testing does not distinguish source of exposure e.g., from air, gasoline, indoor furnishings, etc.) or route of exposure (e.g., inhalation, ingestion).
- Testing for benzene or its metabolites is not covered under OHIP.

- Smokers and those who live in urban (versus rural) areas tend to have higher levels.
- Levels do not correspond to risk of health effects or duration of exposure.
- Benzene is eliminated rapidly from the body (reduced by half in about 8 hours) so depending on the test, it will only indicate exposures in the last 24-48 hours.

Direct measures of exposure include (availability may vary):

- Blood Benzene: Half-life is around 1 hour. Has been used by the Canadian Health Measures Survey, which can be used for comparison to average levels in people living in Canada.
- Urine Benzene: Half-life of about 3 hours.
- Breath Benzene: Half-life of up to 68 minutes.

Metabolites of benzene include (availability may vary):

- Urine S-phenylmercapturic acid (S-PMA): Urinary S-PMA represents less than 1% of benzene exposures. Half-life of S-PMA is 9 hours, and genetic polymorphisms for certain metabolic enzymes can affect test results. This is the test recommended by the Ministry of Labour, Immigration, Training and Skills Development (MLITSD) for occupational medical surveillance programs.
- Urine t,t-muconic acid (t,t-MA): Urinary t,t-MA accounts for approximately 4% of the absorbed dose of benzene. Half-life is 5 hours, thus most informative in the context of assessing recent exposure. Metabolism of sorbic acid (a substance present in many foods) can also produce t,t-MA.
- Urine phenol: Half-life is around 16 hours. Urine phenols is a less reliable indicator of benzene exposure, as it can be elevated from common medications (e.g., bismuth subsalicylate, phenol used for sore throats), benzoate food preservatives, and general environmental and dietary exposures to phenol and other phenolic compounds.

References: ATSDR (2007), Hays et al., 2012 and Health Canada (2019)

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