



Lines of Evidence

This table highlights the approach taken by the Canadian Nuclear Safety Commission (CNSC) to evaluate the scientific information and the findings of environmental and epidemiological studies conducted in Port Hope and other countries.

Environmental decision-making is complex and often based on multiple lines of evidence. A weight-of-evidence evaluation integrates various types of data and takes into account the strengths and weaknesses of different lines of evidence to arrive at an overall conclusion. The following table identifies:

- multiple lines of evidence assessed within the synthesis report
- the CNSC's confidence in each line of evidence
- information obtained from each line of evidence

Based on its evaluation, the CNSC concluded that no adverse health effects have occurred or are likely to occur in Port Hope as a result of the operations of the nuclear industry in the town.

Line of Evidence	Evidence Description	Confidence in Results	Document Source (As referenced in the synthesis report)
<p>Benchmarks and limits for contaminants of potential concern in Port Hope that are protective of human health</p>	<p>Benchmarks to protect human health have been established for uranium, arsenic, ammonia and fluoride. They are based on extensive toxicological information, conservative assumptions and safety factors.</p> <p>The <i>Radiation Protection Regulations</i> specify a radiation dose limit of 1 mSv for members of the public. This dose limit is based on recommendations of the International Commission on Radiological Protection and international reviews of the extensive information on radiation effects. These effects were observed in human populations exposed to radiation and in laboratory studies.</p>	High	<p>US ATSDR 1999 (U) (6) US ATSDR 2007 (As) US ATSDR 2004 (NH3) US ATSDR 2003 (F, HF)</p> <p>US EPA (2007)</p> <p>WHO 2001a (7)</p> <p>Ontario MOE 2008 (5) Health Canada 2008 (19) Ontario MOE 2003 (20) CCME 2007 (22) CNSC 2000 (17)</p>
<p>Solid understanding of levels of potential contaminants of concern in Port Hope</p> <p>Available measurements for the main environmental pathways that could lead to members of the public being exposed to contaminants</p>	<p>Environmental studies conducted in Port Hope cover the last 35 years. Contaminant concentrations have been measured in air, water and soil.</p> <p>Current uranium levels:</p> <ul style="list-style-type: none"> - 0.00028–0.005 µg/m³ in air - 0.00055 mg/L in drinking water - 0.24–93.6 mg/kg in soil (median of 3.1 mg/kg) - Uranium in soil at some sites exceeds CCME guideline of 23 mg/kg due to historical contamination <p>In 1976, Health Canada estimated that the dose from eating only vegetables from Port Hope gardens was 0.0068 mSv/year, well below the public dose limit of 1 mSv/year.</p> <p>In 1981–82, air uranium concentrations ranged from 0.002 to 0.227 µg/m³. In 1988–89, they ranged from 0.001 to 0.0158 µg/m³, a significant decrease due to operational changes. Concentrations have since decreased threefold.</p> <p>Current fluoride levels:</p> <ul style="list-style-type: none"> - 2–22 µg/100cm² in air - <0.25–0.25 mg/L in drinking water <p>Current ammonia levels:</p> <ul style="list-style-type: none"> - 2.2–3.2 kg N/h in air - 0.12–0.21 mg/L in drinking water <p>Current arsenic levels:</p> <ul style="list-style-type: none"> - No emission from Port Hope Conversion Facility - 0.0005–0.002 mg/L in drinking water - Elevated levels in some soils are 	<p>Moderate</p> <p>High</p> <p>High</p> <p>High</p> <p>High</p> <p>High</p>	<p>SENES 2005 (18) MOE 2006 (21) SENES 2008 (23)</p> <p>CCME 2007 (22)</p> <p>Tracy et al. 1983 (55)</p> <p>Tracy and Meyerhof. 1987 (56) Ahier and Tracy 1993 (57)</p> <p>Cameco 2008 (35)</p> <p>Cameco 2008 (35)</p> <p>Ontario MOE 2004 (49) SENES 2008 (23) LLRWMO 2005 (50)</p>

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	attributable to historic waste and are in the range of 1–94 mg/kg (8 mg/kg median)		
<p>Solid understanding of levels of exposure to various contaminants of potential concern (COPC) in Port Hope residents</p>	<p>The main pathways of exposure, inhalation and ingestion are known.</p> <p>The bioavailability of COPC in Port Hope soils has been estimated, particularly for uranium. Uranium bioavailability has also been studied extensively elsewhere in the world. A number of organizations include values for absorption of uranium from the gut.</p> <p>Measured levels of COPCs are available for a range of environmental media, allowing calculation of exposure to COPCs for multiple exposure pathways and receptors.</p> <p>Radiation doses to Port Hope residents from ongoing Cameco operations are estimated annually from effluent and environmental monitoring data. Estimates take into consideration the pathways of exposure and how different forms of uranium behave in the lungs. Doses are estimated for critical groups, and therefore overestimate doses to members of the public. For 2007, doses were as follows:</p> <ul style="list-style-type: none"> - 0.064 mSv/y from the Cameco Port Hope Conversion Facility - 0.004 mSv/y from Cameco Fuel Manufacturing Inc. <p>Indoor exposures to radon, radon decay products and gamma radiation from 1955 to 1993 were estimated as follows, using well-established dose reconstruction methods:</p> <ul style="list-style-type: none"> - indoor gamma: 0.25–0.27 mSv/y - indoor radon: 0.69–0.99 mSv/y 	<p>High</p> <p>Moderate</p> <p>High</p> <p>High</p> <p>Moderate</p>	<p>Cameco 2000. (Derived Release Limit for Cameco Port Hope Conversion Facility)</p> <p>ICRP Publication 68: <i>Dose Coefficients for Intakes of Radionuclides by Workers</i>, 1994.</p> <p>SENES 2008 (23)</p> <p>Cameco 2008 (35)</p> <p>Zircatec 2007 (36)</p> <p>SENES 1995 (60)</p>
<p>Available estimates of risk from exposure to COPCs suggest health effects are unlikely, because of low exposures</p>	<p>Many environmental studies that were conducted in Port Hope indicate that levels of exposure or levels of contaminants in the environment are below levels expected to cause health effects.</p> <p>In 1991, the Ontario MOE assessed the effects of several non-radiological contaminants in Port Hope. The report concluded that:</p> <ul style="list-style-type: none"> ▪ Exposure to reported levels of uranium was not expected to result in adverse human health effects. 	<p>Moderate</p>	<p>Ontario MOE 1991 (51)</p>

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	<ul style="list-style-type: none"> ▪ Exposure to arsenic at reported levels was likely to result in incremental lifetime cancer risk levels of one excess skin cancer every 139 years in Port Hope. The non-cancer risks were considered to be negligible. <p>In the Port Hope Area Initiative’s environmental assessment within Port Hope, the human health risk assessment estimated that adjacent residents had an existing cancer risk from arsenic exposure of between 7.3×10^{-5} and 2.6×10^{-4}, for the various exposure scenarios considered. This range is comparable to a typical Ontario resident’s average cancer risk from arsenic (2.53×10^{-4}), as estimated by the Ontario Ministry of the Environment.</p>		<p>LLRWMO 2005. <i>Port Hope Area Initiative (Port Hope). Human Health and Safety Considerations – Environmental Effects Assessment Report.</i></p> <p>CANTOX 1999. <i>Deloro Village Exposure Assessment and Health Risk Characterization for Arsenic and Other Metals, Final Report.</i></p>
<p>Three diseases identified as plausibly associated with the COPCs in Port Hope: kidney disease, lung cancer and bone cancer</p> <p>Plausible health effects identified from toxicological and radiological literature</p>	<p>Experimental evidence from animal studies indicate that exposure to high concentrations of uranium can lead to kidney damage. Evidence from human exposure to large doses of uranium indicates that cellular effects can occur and are often reversible, but kidney disease has not been observed except in cases of severe/intentional poisoning.</p> <p>High exposure to radon and its radon decay products is known to increase the risk of lung cancer. High gamma ray doses can also cause lung cancer.</p> <p>Very high doses of radium (10 Sv or more) can increase the risk of bone cancer. If ingested, radium deposits mainly in the bone. The threshold for radium to cause bone cancer is 10 Sv.</p>	<p>High</p> <p>High</p> <p>High</p>	<p>ATSDR 1999 (6) Royal Society 2002 (12)</p> <p>UNSCEAR 2008 (16) BEIR VI 1999 (26)</p> <p>UNSCEAR 2008 (16)</p>
<p>No evidence of excess kidney disease</p> <p>Little evidence of excess lung cancer</p>	<p>No statistically significant excess kidney disease mortality in Port Hope residents or in radium and uranium workers, for the entire period of study, was found.</p> <p>There was no statistically significant excess lung cancer incidence or mortality in Port Hope radium and uranium workers.</p>	<p>High</p> <p>High</p>	<p>Kusiak and Howe 1984 (71) HWC 1984 (72) GLHEF 1998 (78) Health Canada 2002 (84) Nair et al. 1984 (95) Howe 2006 (97)</p> <p>Howe 2006 (97)</p>

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<p>No evidence of excess bone cancer</p> <p>No evidence of health effects from occupational exposures</p> <p>No evidence of health effects from other epidemiological studies</p>	<p>There was no conclusive evidence of increased lung cancer risk from residential radon exposure in “problem homes” in the case-control study.</p>	High	Lees, Steele, and Roberts 1987 (91)
	<p>No statistically significant excess lung cancer mortality was seen in Port Hope residents from 1956 to 1997.</p>	Moderate	Health Canada 2002 (84)
	<p>Statistically significant excess lung cancer incidence was seen in Port Hope women from 1986 to 1996. No excess was noted during other time periods or in men.</p>	Low	Health Canada 2000 (79)
	<p>No statistically significant excess bone cancer incidence or mortality was seen in Port Hope residents or radium and uranium workers for the entire period of study.</p>	High	Health Canada 2000 (79) Health Canada 2002 (84) Nair et al. 1984 (95) Howe 2006 (97)
	<p>There was no statistically significant relationship between workers’ occupational exposures and any cause of death or cancer incidence.</p>	High	Howe 2006 (97)
<p>Evidence indicating that increased rates of lung, oral and colorectal cancer and circulatory diseases in Port Hope were not unique to Port Hope residents, but also found elsewhere in the region.</p>	<p>Over 40 epidemiological studies conducted in other countries have found no association between environmental and occupational exposures as a result of the uranium industry and any adverse human health effects.</p>	High	IOM 2000 (9) IOM 2000 (10) ATSDR (6) UK Royal Society 2001 (11) UK Royal Society 2002 (12) Harley et al. 1999 (99) UNSCEAR 2008 (16)
	<p>Excess lung cancer was found in Northumberland County (excluding Port Hope) and an increasing trend for female lung cancer was found in the Haliburton Kawartha Pine Ridge (HKPR) District.</p>	Moderate	Health Canada 2000 (79) Health Canada 2002 (84) HKPR 2008 (86)
	<p>Excess oral cancers (lip, pharynx, nose/sinus) in Port Hope residents were also noted in the HKPR District.</p>	Moderate	Health Canada 2000 (79) HKPR 2008 (86)
	<p>Excess female colorectal cancer was also found in HKPR District.</p> <p>Excess circulatory disease (heart disease, arteriosclerosis, hypertension, and disease of the arteries, arterioles and capillaries) was also found in all of Northumberland County. High prevalence of the main risk factors for circulatory disease (smoking, obesity, physical inactivity, etc.) was found in the Rapid Risk Factor Surveillance System for the HKPR</p>	Moderate	Health Canada 2000 (79) HKPR 2008 (86)

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Occupational exposures not seen to increase the risk of these diseases in Port Hope workers	<p>District Health Unit.</p> <p>Excess rates of rectum cancer and hypertensive disease mortality were found in Port Hope workers in the original and recently updated Eldorado studies, respectively. However, no cause of death or cancer incidence was found to be associated with workers' occupational radiation exposures.</p>	High	Nair et al. 1984 (95) Howe 2006 (97)
Evidence indicating that increased rates of the following were not associated with exposure to radiation and other COPCs in Port Hope: cancer of the breast, kidney, liver, prostate, urinary bladder, skin or lymphoma; leukemia; brain and nervous system cancers; circulatory disease; pneumonia; infections of the skin and subcutaneous tissue; cirrhosis of the liver; birth defects; and. infant mortality	<p>No statistically significant excess leukemia, breast, kidney, liver, prostate, urinary bladder, skin or lymphoma was found in Port Hope residents or radium and uranium workers for the entire period of study. The levels of gamma radiation and heavy metal contaminants were low in Port Hope, so it was not surprising that no excesses were found.</p> <p>No excess birth defects or infant mortality was found and female infants had lower rates of birth defects in Port Hope. Radiation and uranium exposures have not been demonstrated to cause hereditary effects in humans.</p> <p>There is a weak relationship between radiation and brain and other nervous system cancers, and most of the radiation-related tumour risk is benign. Brain cancer is susceptible to inaccurate reporting, because non-brain cancer will often present as brain metastasis.</p> <p>There is no evidence of a relationship between radiation exposure and circulatory disease at exposures below about 1 to 2 Sv. Even Port Hope workers had much lower average cumulative exposures (100 mSv).</p> <p>Pneumonia is an infection of the lungs caused by bacteria, viruses and fungi. Predisposing factors for infections of the skin and subcutaneous tissue include pre-existing skin conditions, trauma, diabetes and immune suppression. The main risk factor for cirrhosis of the liver is heavy alcohol consumption. Excess rates of these three causes of death are not biologically plausibly related to radiation and heavy metal exposures as a result of the Port Hope nuclear industry.</p>	<p>High</p> <p>High</p> <p>High</p> <p>High</p> <p>High</p>	<p>McLaughlin et al. 1993 (75) Health Canada 2000 (79) Health Canada 2002 (84) Nair et al. 1984 (95) Howe 2006 (97) ATSDR 1999 (6) UNSCEAR 2008 (16)</p> <p>GLHEP I 1992 (77) GLHEP 1998 (78) Health Canada 2002 (84) UNSCEAR 2001 (118)</p> <p>Health Canada 2000 (79) UNSCEAR 2008 (16)</p> <p>Health Canada 2002 (84) UNSCEAR 2008 (16) Howe et al. 2006 (97)</p> <p>Health Canada 2002 (84) UNSCEAR 2008 (16)</p>