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Chemicals and Toxicity

Canadians are flooded with conflicting information about toxic chemicals in food, water and consumer products.

Advances in science and technology are making it possible to measure concentrations of chemicals previously too low to detect. They have revealed that the environment and our bodies contain more chemicals than ever before. While this seems alarming, not all chemicals are present in concentrations that have harmful effects.

This ambiguity makes it difficult to distinguish between detected chemicals that are part of background levels normally found in the environment, and levels harmful to human health.

Due to this uncertainty, it is not surprising that chemicals, whether natural or synthetic, are often perceived as a threat. Yet chemicals form the basis of all things; they play a role in every aspect of people's daily lives.

Understanding where to draw the line between "safe" and "toxic" levels of chemicals is critical for public policymaking.

Measuring Toxicity

Toxicologists work in units that describe small amounts of chemicals. One common unit of measurement is "parts per million", or ppm. One ppm is roughly equivalent to three drops in a bathtub filled with water.

Some chemicals can be toxic at very low concentrations whereas others only cause adverse effects when present at high concentrations.

The toxicity of chemicals in humans is affected by dosage, as well as by factors including the route of exposure and interaction with other chemicals and the environment.

Considering these factors, toxicologists calculate the *risk* that exposure to a chemical will cause significant harm to human health. They conduct a human health risk assessment by examining the chemical's adverse health effects (*hazard*) as well as the amount of chemical entering the human body and the duration of its presence (*exposure*).

Formula: Risk = Hazard * Exposure

As human toxicity data are limited (originating from records of accidental exposure or studies examining long-term occupational exposure), data are collected from *in vivo* laboratory experiments on animals or *in vitro* cell-based test systems, and extrapolated to estimate hazard in human populations.

The lack of data is one of many sources of uncertainty incorporated in risk assessments. However, risk assessments are still used to estimate levels safe for human exposure.

A dose-response graph (see Figure 1) describes the dose at which chemicals have adverse effects. It can be used in risk assessments to calculate the potential hazard of chemicals to humans.

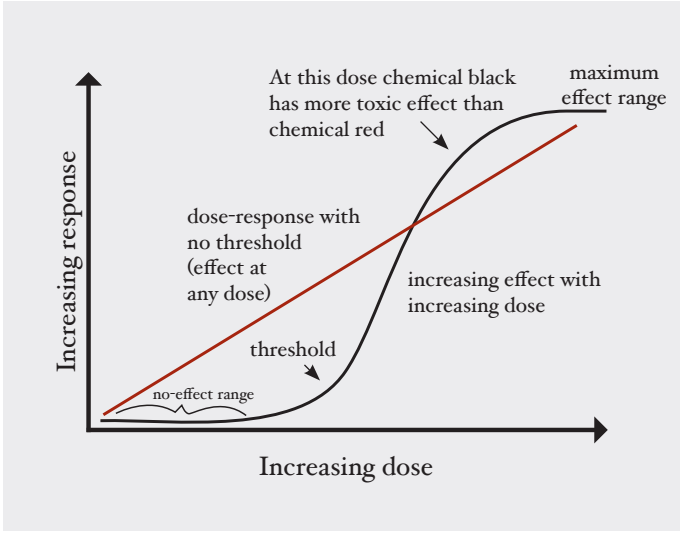


Figure 1: A typical dose-response curve used in the assessment of chemical hazard. The black curve illustrates a chemical with a threshold dose, meaning it is not toxic at low doses but becomes increasingly toxic after reaching a threshold dose. At high doses, increasing the dose no longer increases the effect. The red curve characterizes 'non threshold' chemicals for which the effects are toxic at any dose and increase as the dose increases. Increasing 'effect' means an increasing adverse response, which can range from temporary irritation to permanent damage or death. Many carcinogens are considered to be 'non threshold' chemicals.

Managing Toxicity

There are various ways in which toxic chemicals are managed through policy. Common examples include:

- *Self Regulating* through voluntary codes or standards set by industry or users themselves;
- *Educating* users by communicating proper use and disposal of chemicals;
- *Encouraging* specified behaviour through subsidies or tax breaks; and
- *Regulating* how chemicals are handled, used and discarded, including prohibition of use or ownership.

In Canada, chemicals known to traverse international or interprovincial borders via air or water are managed federally. Provinces have jurisdiction over chemical management issues of a more local interest, such as zoning. Other matters, like agriculture and the environment, are subject to both federal and provincial jurisdiction.

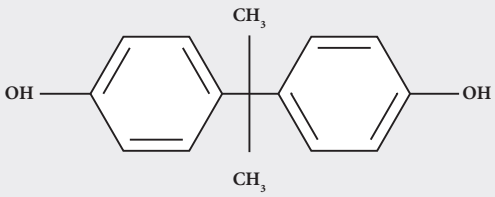
When determining the appropriate way to manage a chemical, factors to consider include:

- Availability of suitable alternatives;
- Cost-benefit analysis results;
- Whether people can control their exposure to the chemical; and
- Exposure of susceptible populations, including pregnant women, infants, children, the elderly, and people with weak immune systems.

The following examples illustrate some factors involved in developing policies to manage toxic chemicals.

Case Study:

Bisphenol A (BPA) in baby bottles



In 2010, Canada was the first country to take regulatory action leading to a restriction and prohibition on the use of bisphenol A (BPA) in certain consumer goods.

BPA is an industrial chemical used in plastic-based products, ranging from refillable water bottles to the protective liners inside metal cans that make it possible to store food longer without spoiling.

The risk

Numerous studies have demonstrated that BPA is an endocrine disrupting chemical (EDC) with an ability to affect the hormonal systems of animals and humans. BPA mimics the female sex hormone estrogen and, upon entering the body, can lead to reproductive impairment or cancer. Animal studies have shown EDCs are more likely to disrupt hormonal systems early in life compared to adulthood.

Humans are exposed to BPA when it leaches into foods and beverages from plastic packaging or storage containers.

Heating or boiling substances in plastic containers (warming formula in baby bottles, for example) can facilitate the release of BPA. BPA can have disproportionately more severe effects on infants because their organs are rapidly developing and small size means that a small amount of BPA is at a higher concentration than in adult bodies.

The policy

Under the Chemicals Management Plan, a policy and program under the authority of the Canadian Environmental Protection Act (CEPA), chemicals are screened, prioritised and categorised for further risk assessment. BPA was identified as a high priority chemical because of its potential toxicity to the reproductive system and other endocrine functions.

Results of the risk assessment showed that BPA levels leaching out of plastics were below levels where the chemical is harmful to both the general population and most susceptible populations.[1,2] However, results for infants showed only a small difference between exposure level and effect level.

Weighing available and relevant scientific evidence, which showed the potential for increased exposure and developmental sensitivities of infants to BPA, and knowing that alternatives to BPA were readily available led the Canadian government to ban BPA in plastics used to make baby bottles. This approach was consistent with the precautionary principle.

Definition: The *precautionary principle* is a term used in risk management to describe an approach whereby action is taken to prevent potentially serious harm, even if scientific uncertainty remains.

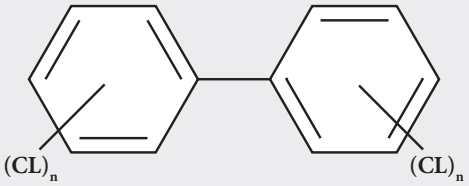
Other governments have followed suit. The European Union banned the manufacture and sale of BPA-containing baby bottles in 2011. In Denmark, BPA was banned in all food products for children aged three and under. In Australia, manufacturers voluntarily agreed to phase out BPA in baby bottles. As of 2011, the U.S. has not taken federal-level action on BPA.

1 http://www.hc-sc.gc.ca/fn-an/securit/packag-emball/bpa/bpa_hra-ers-eng.php

2 http://www.ecoaction.gc.ca/news-nouvelles/20080418-5-eng.cfm

Case Study:

Polychlorinated biphenyls in food and water



Polychlorinated biphenyls, or PCBs, are industrial chemicals that have the potential to interfere with essential hormonal systems in animals and humans. The manufacture of PCBs in Canada has been prohibited since 1977. PCBs were once used in the production of electrical transformers and capacitors, as heat exchange fluids, paint additives and plastics, and as flame retardants in the coating of electrical wires.

Once introduced into the natural environment, PCBs remain intact for years. PCBs have been thoroughly studied for decades and have been shown to cause adverse effects on the immune, reproductive and nervous systems in animals. They also have the potential to cause cancer in animals and humans.

The risk

PCBs do not degrade easily as they are designed to withstand extreme conditions when used to insulate and cool industrial transformers and capacitors.

They can also evaporate at certain temperatures and travel through the atmosphere to regions where there is little to no human activity, such as the Canadian Arctic. PCBs accumulate in snow, ice and tissues of wildlife and are transferred through the food chain, meaning that even though production has significantly decreased, people in the Arctic continue to be exposed to PCBs through the meat they eat.

The policy

In Canada, the use of PCBs is regulated under the Canadian Environmental Protection Act (CEPA). Storage, use and environmental release of PCBs had been limited to small amounts until 2009, when they were almost entirely phased out. PCBs are still used by some industries where viable chemical alternatives are unknown, but users are required to label and report their usage, storage and destruction.

Canada has made several international commitments to phase out PCBs:

North America Free Trade Agreement (1995)	Bans environmental PCB release and high levels of PCBs in equipment
North American Agreement on Environmental Cooperation and Regional Action Plans (1994)	Uses environmentally sound management toward existing PCBs and outlaws further release of PCBs
Stockholm Convention (2004)	Reduces unintended persistent organic pollutant emissions, including PCBs

Despite these measures, PCBs and similar persistent pollutants remain ubiquitous and continue to pose a risk to human and environmental health.

Identifying and Regulating Toxic Chemicals

Determining the toxicity of chemicals is a complex process. Scientists consider numerous variables including the amount of chemical present, the susceptibility of individuals exposed and whether chemical exposure is hazardous in the long or short term.

Risk assessments also rely on data availability. When human or animal data on a chemical are scarce, computer models and other methods to estimate toxicity thresholds are used, which may introduce additional uncertainty.

Policymakers rely on scientists to develop risk assessment data and understand that uncertainty is inherent in this process. Based on the scientific evidence, but armed with policy tools and recognising available chemical alternatives, policymakers can make decisions regarding chemical exposure to reduce the risk to the Canadian population.

What's on the horizon?

New chemicals, emerging biotechnologies, and better detection and identification technologies will lead to future challenges and solutions. Emerging fields such as nanotechnology pose challenges as potential health hazards and methods for measurement of exposures are not well established.

New molecular biology techniques and computer models that can replace the use of animal models in the evaluation of toxic chemicals are improving our insights into human health effects.

The recently enacted Canada Consumer Product Safety Act includes mandatory reporting of adverse health incidents to Health Canada and requires that products be traceable to production sources in the case of incident and recall.

Further Reading

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About *SciencePages*

SciencePages (www.sciencepages.ca) is an initiative of the Partnership Group for Science and Engineering (www.pagse.org). SciencePages aims to increase discussion on topical issues that have science and engineering at their core, by summarizing the current state of knowledge and policy landscape. Each issue is prepared and reviewed by a multi-disciplinary team and is published quarterly, free of charge.

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