PRIMER ON

TOXIC SUBSTANCES

POLLUTION PROBE

CLEAN AIR. CLEAN WATER.

POLLUTION PROBE is a non-profit charitable organization that works in partnership with all sectors of society to protect health by promoting clean air and clean water. Its approach is to define environmental problems through research, to promote understanding through education and to press for practical solutions through advocacy. Its objective is to advance public policy that results in positive and tangible environmental change.

Pollution Probe was established in 1969 following a gathering of 240 students and professors at the University of Toronto to discuss a series of disquieting pesticide-related stories that had appeared in the media. Early issues tackled by Pollution Probe included urging the Canadian government to ban DDT for almost all uses, to eliminate the use of phosphates in detergent and to reduce acid rain–causing emissions from base metal smelting operations. During the 1980s, Pollution Probe encouraged curbside recycling in 140 Ontario communities and supported the development of the Blue Box program. Pollution Probe has issued a wide range of books and other publications, including *Profit from Pollution Prevention*, *The Canadian Green Consumer Guide* (of which more than 225,000 copies were sold across Canada) and *Additive Alert*.

Pollution Probe continues to play an instrumental role in the development and implementation of practical solutions and public policy in Canada. Recent achievements include regulations limiting emissions from smelters, sulphur levels in fuel and emissions from vehicles (including greenhouse gases from passenger cars and light trucks). To raise public awareness about the interrelationships among vehicle emissions, smog, climate change and related human respiratory problems, Pollution Probe has held an annual Clean Air Campaign every year since 1993. This event has engaged more than 800 workplaces throughout Ontario and beyond. The campaign is Pollution Probe's most visible effort to inform the public about the health risks of air pollution, to promote practical air quality solutions, and to reduce traffic congestion. The Clean Air Campaign aims to inspire individuals to choose more sustainable modes of transportation – walking, cycling, public transit, carpooling, telecommuting – rather than driving to work alone. Since 2000, when reporting of pollutants was introduced to the program, commuters have prevented over 5200 tonnes of air pollutants (NO_x, SO_x, VOCs, CO, CO_2) from entering our atmosphere. The Clean Air Campaign was also integral to the Ontario Ministry of the Environment's development of the Drive Clean mandatory vehicle emissions testing program.

Pollution Probe currently has standing programs on air pollution, water pollution and human health, as well as special issue programs that focus on transportation, energy systems, children's health and the environment, climate change and the removal of human sources of mercury from the environment. In the development of innovative and practical solutions, Pollution Probe draws on sound science and technology, mobilizes scientists and other experts and builds partnerships with industry, government and communities.

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POLLUTION PROBE'S series of educational primers on environmental topics is intended to inform Canadians about current environmental issues. The primers set out the scientific basis for concern, potential solutions and the policy tools available. Each primer focuses on what is being done and what more can be done by governments, businesses and individuals on the issue in question. The primers are researched and written under the direction of Pollution Probe's Chief Executive Officer and are reviewed before publication by scientists, non-governmental organizations, industry experts, policy-makers and others who have technical expertise in the subject area.

For information on Pollution Probe's primers and other publications, visit our website at **www.pollutionprobe.org/Publications**.

Primer on Energy Systems in Canada (2011) explains that energy systems can be thought of as the interconnected elements of technology and infrastructure that transform natural sources of energy into useful services that deliver access, convenience, comfort and other amenities.

Primer on Automobile Fuel Efficiency and Emissions (2009) explains energy use in the modern automobile, the environmental impacts and the technologies to minimize both.

The Acid Rain Primer (2006) contains an in-depth discussion of the science of acid rain and the policy and regulatory history of this fascinating environmental and health issue.

A Guide to Climate Change for Small- to Medium-sized Enterprises (2006) explains how businesses can take action to reduce their greenhouse gases and lower their energy costs, as well as managing the risks and opportunities associated with climate change.

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Primer on Bioproducts (2004) provides an overview of the ways bioproducts are made and highlights some of the issues that bioproduct technologies raise for Canadians.

Primer on Climate Change and Human Health (2004) describes the ways in which a more variable climate may impact Canadians' health, reviews actions taken by governments and industries, and examines what individuals can do to reduce greenhouse gas emissions.

The Source Water Protection Primer (2004) explains the water cycle, identifies threats to water sources, focuses on watersheds as the ideal management unit and identifies steps to consider when developing local source water protection plans.

Emissions Trading Primer (2003) explains the concepts behind emissions trading, describes the ways in which it works and provides examples and case studies.

Primer on the Technologies of Renewable Energy (2003) explains the concept of renewable energy and the rationale for shifting energy generation towards cleaner and less greenhouse gas-intensive sources.

Mercury in the Environment: A Primer (2003) provides an overview of the mercury cycle, releases to the environment, transportation and deposition around the world and the uptake and accumulation of mercury in the food chain.

The Drinking Water Primer (2002) examines the two sources of drinking water – groundwater and surface water – and the extent to which Canadians depend on them.

The Smog Primer (2002) explains what smog and the pollutants that create it are and highlights the major source of these pollutants: the burning of fossil fuels for transportation and energy

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ACKNOWLEDGEMENTS

This project has received funding support from the Government of Ontario. Such support does not indicate endorsement by the Government of Ontario of the contents of this material.

Pollution Probe thanks the following individuals and organizations for volunteering their time and expertise in reviewing drafts of this document during its development and for providing feedback on its content and structure:

Yusuf Alam, Josephine Archbold, Louise Aubin, Marco Belmont, Eric Bristow, Jean Carpentier, Craig Crawford, Mike Dutton, Environment Canada, Health Canada, Norm Huebel, Jules Lauzon, Ken Ogilvie, Ontario Ministry of the Environment, Erica Phipps, and Rich Whate.

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ISBN 978-0-919764-68-2

This primer was developed and prepared for publication by Melissa DeYoung, Pollution Probe.

Support from the following in the development of this primer is also gratefully acknowledged:
Walter Dick, Mary Pattenden, and Julie Sommerfreund.

Editing Services: Linda Klaamas, Fouled Language Inc. / Ann Martin, ReVision Editorial Services / Ruth Miller, On-Line Editing Ltd.
Design, Illustrations & Layout: franklinHEAVY

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FOREWORD

POLLUTION PROBE is pleased to introduce its *Primer on Toxic Substances*. The management of toxic substances is a complex issue that must deal with many uncertainties, yet it is unquestionably important because it affects not only our own lives but also those of generations to come.

Our understanding of toxic substances and their effects on people and the environment continues to change as relevant research evolves. Even the experts do not always agree on the nature of the threats that these substances pose.

The reality is that toxic substances not only surround us but are in us. They are part of our daily lives. The cellphone that you just put down to read this is treated with flame retardants. The energy-saving fluorescent light that you just turned on uses a bulb containing mercury. And the soda that you are sipping is in a can with a liner containing BPA.

A day rarely goes by when we do not hear a news story about a recall on lead-contaminated children's toys, a residential evacuation due to dioxins from a nearby industrial fire, or people – and even pets! – getting sick from eating contaminated food. But how many of us understand the nature of exposure, risk and hazard in this context? How many of us have sufficient knowledge of the ways in which toxic substances enter our home to enable us to reduce their impact? Without such knowledge, fear can fill the void, leading to irrational responses.

The purpose of this primer is to fill the gaps in our understanding with information, which will enable us to participate more fully in discussions and activities aimed at minimizing the release and use of toxic substances. This primer is not intended to be the last word on the subject; rather, it serves as a first substantive step in making sense of the issues. The Government of Ontario's *Toxics Reduction Act* inspired Pollution Probe to develop this primer and for this reason, some of the content is oriented towards issues that exist in Ontario. I believe, however, that the primer has value as a national informational resource. The primer summarizes the current understanding of toxic substances, how they are identified, their potential effects on human health and the environment, and possible sources of exposure. It surveys the roles played by government and industry, and calls attention to actions that we can all take to foster a safer, healthier future.

Bob Oliver

Chief Executive Officer
POLLUTION PROBE

March 2012

TOXIC CHEMICALS THREATEN WILDLIFE, REPORT SAYS

– Toronto Star, November 3, 1987

ALARM BELLS SOUND OVER THREAT OF MERCURY CONTAMINATION

– The Chronicle Journal, Northwest Ontario, March 9, 2008

TOXIC BREW; SYDNEY RESIDENTS LIVE IN FEAR AS OFFICIALS DEBATE

– Toronto Star, May 7, 2001

BIG GREAT LAKES TROUT THE MOST TOXIC, REPORT SAYS

– CTV News, July 13, 2011

ASBESTOS BACK IN THE SPOTLIGHT

– Toronto Star, June 14, 2011

EXPOSURE TO BPA MAY BE GREATER THAN PREVIOUSLY THOUGHT

– Toronto Star, June 6, 2011

SMALL AMOUNTS OF ARSENIC FOUND IN CHICKEN FEED: FDA

– Toronto Star, June 8, 2011

RENOVATIONS COULD ADVERSELY AFFECT YOUR FAMILY’S HEALTH: STUDY

– Toronto Sun, March 6, 2011

HEALTH MINISTER PROPOSES NEW GUIDELINE ON TOXIC METAL IN KIDS’ JEWELRY

– Ottawa Citizen, July 25, 2011

TOXIC EMISSIONS DOWN; DOFASCO, STELCO PRAISED FOR TAKING LEAD

– The Hamilton Spectator, July 26, 2000

WHY YOU SHOULD READ THIS PRIMER

You have most likely seen headlines similar to the ones on the facing page in your local newspaper, in magazines or online. They may have prompted you to ask, what is BPA and on what grounds is it declared toxic? Why is asbestos still a problem? And, how does cadmium find its way into children's jewellery? You may also wonder what such headlines mean for you and how you can protect yourself and your family from exposure to toxic substances. Sorting through the vast amount of information related to toxic substances can be daunting. Opinion and scientific evidence are wide-ranging and continually evolving. The sheer number of chemical substances in use today often leaves us confused – which ones require our attention?

Headlines like those cited are not uncommon. We are learning more about the effects of toxic substances every day. Every substance has the potential to be toxic to some degree, but a number have been linked to possible harmful effects on human health and the environment. Discussions that weigh the benefits of using certain substances against their potentially toxic effects have been played out publicly in recent decades, reflecting concerns on the part of government, industry, environmental health and civil society groups, and individuals. As we continue to learn more about the nature of new substances and the long-term effects of exposure to familiar substances (such as lead, cadmium and mercury), these discussions will continue to evolve.

This primer focuses on the chemical substances that are identified as toxic substances under the *Canadian Environmental Protection Act*, 1999 (CEPA 1999) or prioritized under the *Ontario Toxics Reduction Act* (TRA). Some feel, however, that it should not be assumed that chemical substances identified as toxic under CEPA 1999 or prioritized under the TRA are the only ones that exist or that there has been general agreement that current legislation adequately deals with their assessment and management. We have chosen to address toxic substances from the perspective of how they are identified under prevailing law because these substances have either been measured against specific criteria, generated conclusive scientific data or otherwise been considered for management. In addition to CEPA 1999, there is specific legislation for pesticides and pharmaceuticals, such as the *Pest Control Products Act* and the *Food and Drugs Act*. Both types of substances pose complex questions that require lengthy discussion beyond the scope of this primer.

Strategies for dealing with toxic substances often focus on controlling point-source releases (i.e., releases into the environment from a single, identifiable site – usually industrial – where the substance was produced, stored or used). Releases of toxic substances from consumer products and non-point sources (i.e., releases of the same type that are too numerous to trace to a point source) are more difficult to manage. While many stakeholders are working to address the use and management of toxic substances, it is beyond the scope of this primer to discuss each one's contribution. Instead, we will focus on the roles played by government, industry and individuals, and on the ways we can all contribute to a safer, healthier future.

The aim of this primer is to provide a solid introduction to the main concepts necessary to an understanding of the issues related to toxic substances. Once we understand, for example, the environmental impacts of mercury contamination or the implications of ruling bisphenol A (BPA) "toxic," we will be in a better position to avoid exposure in our daily lives and prevent potential environmental impacts, where possible. And when we read another headline like those on the facing page, we will have a better grasp of the issues, their implications and possible responses.

PRIMER OUTLINE

This primer begins with an introduction to some of the bases of our current understanding of toxic substances. Then, chapter by chapter, it describes what toxic substances are, how they affect human health and the environment, where they are found and how various stakeholders are working to address and to manage them.

The INTRODUCTION outlines some of our current understanding of chemistry and the links between toxic substances, the environment and human health. The introduction identifies some of the key issues associated with toxic substances and their management.

CHAPTER ONE provides an overview of the criteria used by different jurisdictions to identify toxic substances. It presents some of the main concepts used to explain why some chemical substances are considered toxic and draws attention to the challenges facing those who seek to reduce or to eliminate the use or release of these substances.

CHAPTER TWO outlines some of the human health effects that have been associated with exposure to toxic substances. The chapter deals with the current understanding of these effects: some conclusions have been well established, but others are still the subject of debate and research.

CHAPTER THREE describes the conditions that have been linked to the presence of toxic substances in the environment. The environment often acts as an early warning system, alerting us to the effects that certain substances may have on human health. This chapter uses the Great Lakes Basin as a case study.

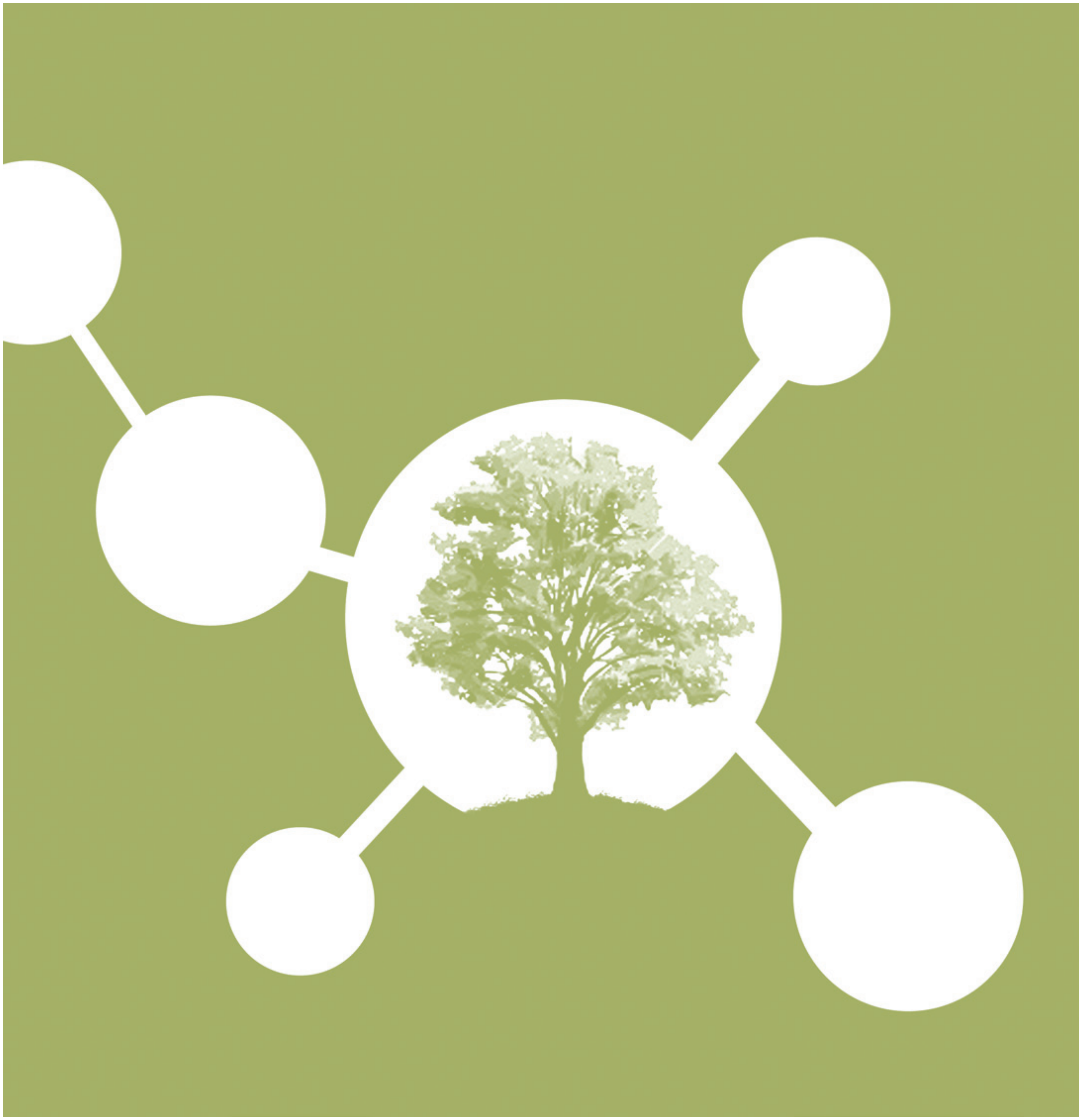
CHAPTER FOUR explores where toxic substances are found and how exposure can occur. This chapter differentiates types of releases (whether naturally occurring or as a result of human activity) and varieties of use (in industry and consumer products). It also deals with exposures related to diet, indoor and outdoor air quality, dust, drinking water and the workplace.

CHAPTER FIVE focuses on the role government plays in addressing toxic substances. The chapter examines some of the regulations and management strategies employed at the federal, provincial and municipal levels to deal with toxic substances, as well as Canada's participation in international initiatives.

CHAPTER SIX is concerned with industry's management of toxic substances and their releases. It looks at consumer products, recycling, environmental labelling and the technologies employed to reduce the creation, use and disposal of toxic substances. It also outlines industry reporting requirements and voluntary industry initiatives.

CHAPTER SEVEN focuses on how individuals can manage toxic substances in their day-to-day lives. The chapter builds on what we have learned so far, taking the concepts outlined in the primer and applying them to our own attempts, as individuals, to navigate the vast amount of information related to toxic substances and identify areas of concern. Encouraging such attempts is the primary goal of this primer.

A glossary of terms and list of selected references and useful websites have also been provided.



INTRODUCTION

Toxic chemicals threaten wildlife, report says – Toronto Star, November 3, 1987

Chemistry has played a major role in helping people understand the world around them and find ways to improve it. Everything in the world, from the air we breathe to the clothes we wear, is composed of chemicals in various combinations. Chemistry has enabled us to transform naturally occurring substances, such as metals, rubber and crude oil, into other chemical forms, which are used in the production of the necessities and luxuries that are an integral part of our daily lives. Chemical substances have vastly improved our standard of living and helped save lives through medical advances.

The production of chemical substances to meet our needs has a long history. About three thousand years ago, our ancestors combined tin and other chemical elements with copper to produce the material that we know as bronze – the world's first synthetic metal (alloy). Bronze was more durable than other available materials and led to the development of superior tools, weapons and machinery. We have learned to work with other naturally occurring chemical substances to produce items such as concrete, soap and medicine. Over the centuries, chemistry has evolved; no longer merely the study of the behaviour of chemicals in the natural world, it is now capable of identifying and isolating chemical elements, exploring the atomic makeup of molecules and creating new synthetic materials.

During the last century, scientific findings and public awareness continued to grow. In 1907, the production of the first synthetic polymer, a plastic called Bakelite, opened the door to the development of thousands of new polymers. Today more than 56 million chemical substances are listed in the American Chemical Society registry (although only a small number are currently in use in Canada or elsewhere), and new substances are added every day. Chemical substances have allowed us to develop new technologies and materials, to respond to consumer demand, and to improve health, safety and security. Products that are commonplace today, like computers, appliances and vehicles, would not be possible without modern chemistry. There are some chemical substances, however, whose effects on human health and the environment are not fully understood. We must work to ensure that precautions are taken in the regulation and management of these substances and that we are in position to respond in a timely manner to new scientific discoveries.

Published in 1962, Rachel Carson's *Silent Spring* provided a new perspective on chemical substances and changed the way the environment was viewed. The book raised public awareness of the effects of the unregulated use of post–World War II chemicals and insecticides on nature's delicate balance. Many consider Carson's book to be the catalyst of the environmental movement.

In *Silent Spring*, Carson states,

> ...the central problem of our age has therefore become the contamination of man's total environment with such substances of incredible potential for harm—substances that accumulate in the tissues of plants and animals and even penetrate the germ cells to shatter or alter the very material of heredity upon which the shape of the future depends.

Although Carson was referring to DDT, her comments also apply to some of the toxic substances that we deal with today.

During the 1970s and 80s, a series of environmental incidents contributed to increased public awareness and concern. The levels of toxic waste in tar ponds containing runoff and residual material from a former steel mill in Sydney, Nova Scotia, were shown to have affected the health of the surrounding community. The derailment of 21 railway cars in Mississauga, Ontario, in 1979, resulted in a fire, the release of dangerous chemicals and the largest peacetime evacuation in North American history. Significant quantities of the toxic substance dioxin, which concentrates in the environment and endures in our bodies, were found in fish and in herring gull eggs around the Great Lakes. Of course, the strong public reaction to such events is not the only way that people have expressed their concern about toxic substances. Still, these events highlight the need for the public, regulators, civil society groups and industry to address environmental issues.

As a result of growing public awareness of environmental events, there was considerable pressure placed on government to control pollution and avert similar situations, which resulted in the creation of the Department of the Environment (now Environment Canada) in 1971. It followed on the heels of the establishment, in 1970, of the Environmental Protection Agency in the United States. At the international level, the United Nations Conference on the Human Environment, held in Stockholm, Sweden, in 1972, proposed the creation of a global body to act as the environmental conscience of the UN. The establishment of the United Nations Environmental Programme (UNEP) marked the formal recognition by the international community that environmental considerations must be taken into account in all development activities. A Canadian, Maurice Strong, acted as UNEP's first executive director.

The creation of these government and regulatory bodies prompted further research into critical environmental issues. The resultant studies have provided the impetus for new environmental legislation worldwide. In recent decades, environmental conferences, conventions and working groups have advanced our knowledge and co-operation regarding human health and environmental issues, including those related to toxic substances.

Not all chemical substances are necessarily toxic to humans or the environment, but every chemical substance, including water, has the potential to be so. Toxic substances are not a homogeneous group: each has unique characteristics. Many have the potential to be used safely; however, they require appropriate management. Whether or not a substance exhibits a toxic effect depends on many factors, including the inherent hazardous properties of the substance, and the timing, level and amount of the exposure. When evaluating the possible effects of a toxic substance, one must take into account the likelihood that a hazardous level of exposure will occur.

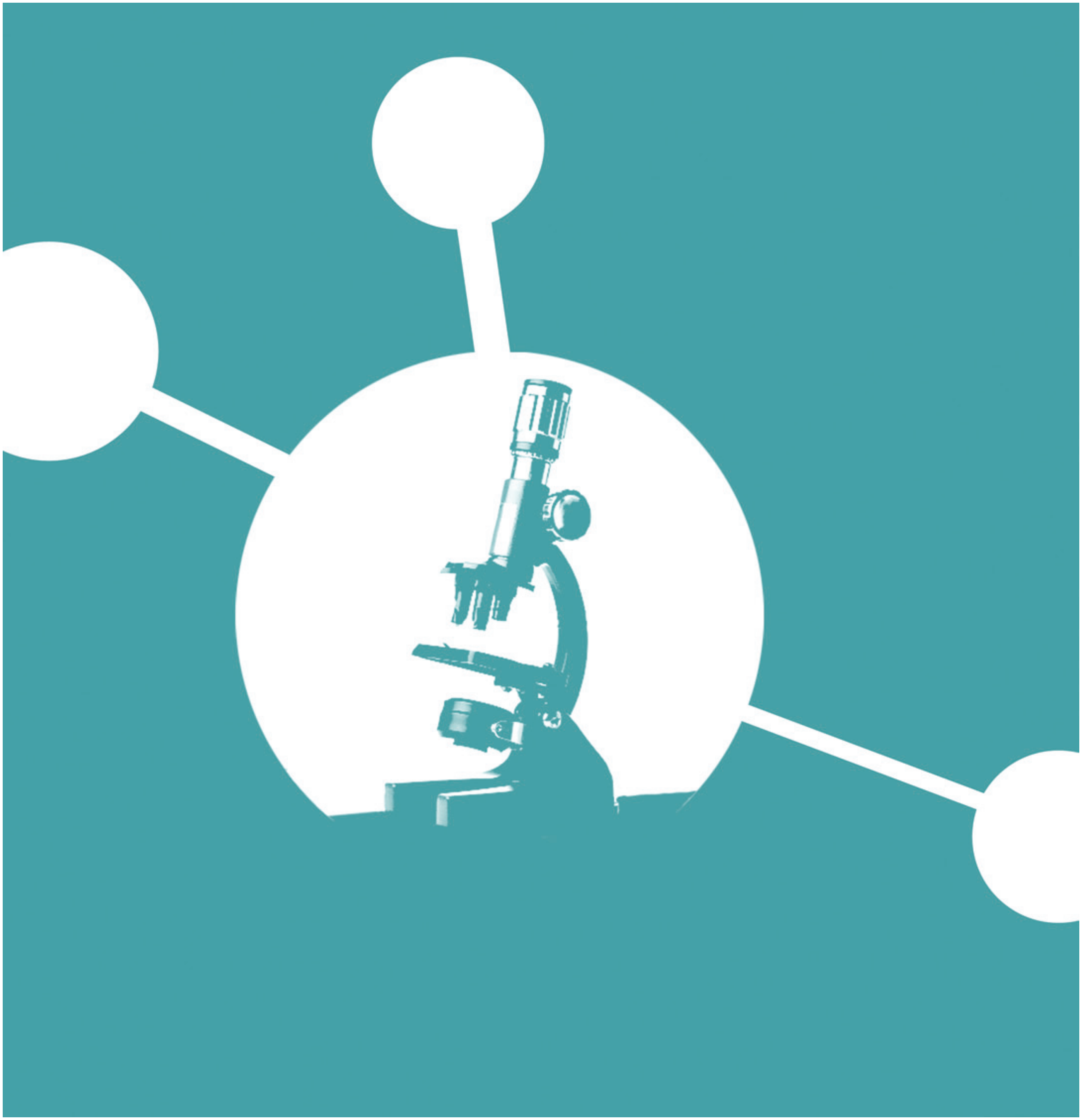
The potentially toxic nature of some chemical substances has been known for centuries. Evidence gathered by archaeologists indicates that, thousands of years ago, poisonous plants and animal venoms were sought for their toxic effects. Poison was the weapon of choice for political assassination and suicide in many parts of the world from the first century to the Middle Ages. Most of the knowledge about poisons and antidotes was collected in scholarly works, such as *The Book of Venoms*, written by a monk in 1424. The book describes the poisons known at that time, as well as their uses and treatments. In the fifteenth century, links between illnesses and occupational exposure to certain chemical substances were discovered. Over time, illnesses were connected to mining and processing materials such as lead, the mercury in hat making (hence the phrase “mad as a hatter”) and the inhalation of silica dust when working with stone.

It has been only in the past century, however, that public awareness of toxic effects has become widespread. In 1956, a manufacturing facility in Minamata, Japan, used methylmercury to manufacture plastic and disposed of contaminated waste in the local bay. This led to a buildup of methylmercury in fish and shellfish, which were staples of the diet of the local population. Hundreds of residents died and several thousand were seriously ill from mercury poisoning. In 1969, a pulp and paper mill in northwestern Ontario released mercury, used in the production of chlorine for paper bleaching, into the English-Wabigoon River system, leading to the contamination of fish and threats to the health of local residents.

The federal *Canadian Environmental Protection Act* (CEPA) was introduced in 1988. In 1994, it added a new requirement – that all chemical substances introduced after 1987 must be assessed for the risk that they pose to human health and the environment before they enter the market. When this new requirement was established, however, there were already approximately 23,000 substances that had been on the market prior to 1987 and that had not been fully assessed: some had been in widespread commercial use for decades.

Much has been done in recent years to close potential gaps in regulation. In response to growing public concern about the environment, the Government of Canada amended CEPA in 1999. Using the mandate of CEPA 1999, Environment Canada and Health Canada have established a process to categorize all of the 23,000 chemical substances not previously assessed. When the initial stage of prioritization was completed in 2006, 19,000 substances did not meet the criteria for categorization as identified in the Act, and about 4,300 substances were identified as priorities for further action. Any substance that meets the criteria for toxic substances as defined by CEPA 1999 is recommended for addition to the List of Toxic Substances (Schedule 1) and subject to various risk-management measures. Certain toxic substances (i.e., those that are persistent, bioaccumulative, inherently toxic to the environment or human health and primarily a result of human activity) are considered for virtual elimination (i.e., no measurable release) under CEPA 1999.

Civil society and environmental health organizations have taken on the important role of working with government and industry to educate the public on toxic substances. As a result of government action, public awareness and industry initiatives, more attention is now being paid to toxic substances than ever before. This has resulted in advances in scientific knowledge, safer alternatives and better means of protection.



Chapter One
WHAT ARE TOXIC SUBSTANCES?

Asbestos back in the spotlight – Toronto Star, June 14, 2011

This chapter takes a closer look at toxic substances that are defined or identified under prevailing Canadian law. These substances tend to be the most familiar to Canadians and are those that have had, at the very least, some sort of testing or assessment done in an attempt to address and manage them.

> All things are poison and nothing is without poison. Solely the dose determines that a thing is not a poison.
> (Paracelsus, 1493 – 1541)

The potential for any chemical substance to have a toxic effect was recognized in the sixteenth century by Paracelsus, one of the pioneers of toxicology. He concluded that any chemical substance could be toxic, depending on the dose, and that some substances that are beneficial at one dose are toxic at another. We now know that there are other factors that contribute to the potential toxic effects of a substance. These factors will be discussed in this chapter.

A toxic substance is often described as a chemical substance that might be harmful to the environment or human health, but this description does not take into account the fact that most substances that are not considered toxic can have harmful effects depending on the dose and the route, timing and duration of exposure. For instance, common table salt is safe to use in very small amounts but can cause death if consumed in large quantities. Conversely, there are many toxic substances that have real benefits if used safely and properly managed. For example, chlorine gas can be lethal to humans if inhaled, but when added to water, chlorine acts as a disinfectant, reducing the spread of harmful bacteria and protecting public water supplies.

So what determines whether a chemical substance should be considered a toxic substance?

How Are Toxic Substances Identified?

In general, the term "toxic substances" refers to those chemical substances that are considered to carry a risk of serious harm to human health or the environment. However, there is no single definition or profile of such substances. Each governmental authority describes toxic substances according to its own criteria.

According to Section 64 of CEPA 1999,

> a substance is considered toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that:
>
> a) have or may have an immediate or long-term harmful effect on the environment or its biological diversity;
>
> b) constitute or may constitute a danger to the environment on which life depends; or
>
> c) constitute or may constitute a danger in Canada to human life or health.

The current List of Toxic Substances under CEPA 1999 contains more than 90 chemicals or families of chemicals that together represent over a thousand unique substances. Other federal legislation also applies to the management of toxic substances, including the *Food and Drugs Act*, the *Pest Control Products Act*, the *Hazardous Products Act* and the *Canada Consumer Product Safety Act*. If the requirements of these acts and CEPA 1999 overlap, the government has the authority to select the measures that best apply.

The federal government also requires major industrial emitters to provide release data for pollutants that are included in the National Pollutant Release Inventory (NPRI). The NPRI list of substances is compiled by means of a multi-stakeholder consultation process and currently contains 347 chemical substances. NPRI uses the following criteria to determine which chemical substances should be included in the inventory:

- Is the substance manufactured, processed or otherwise used in Canada?
- Is it a health and/or environmental concern?
- Is it released to the Canadian environment?
- Is it present in the Canadian environment?

While the substances listed on NPRI are considered to be of concern for human health and/or the environment, they are not all toxic according to the criteria of CEPA 1999. However, given that these substances have met the criteria for NPRI, the provincial government in Ontario has prescribed the list as a starting point for its Toxics Reduction Strategy.

The Ontario government focuses on prescribing toxic substances that may harm the environment and/or the health of living organisms, including humans, wildlife and plants. Prescribed toxic substances are listed under TRA and include the substances specified in the federal NPRI plus acetone (*Ontario Regulation* 127/01). When implementing the first phase of TRA, the province selected 47 "priority substances or substance groups" from the NPRI for immediate action (for the names of these substances, see http://www.e-laws.gov.on.ca/html/source/regs/english/2009/elaws_src_regs_r09455_e.htm#BK39). Action on the remaining 300 substances will be phased in over time.

Other jurisdictions use different criteria to identify toxic substances. For example, the European Union uses the term "substances of very high concern" (SVHC) in its *Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation* (REACH). SVHC are

- carcinogenic, mutagenic or toxic to reproduction (CMR);
- persistent, bioaccumulative and toxic (PBT) or very persistent and very bioaccumulative (vPvB); and/or
- identified, on a case-by-case basis, according to scientific evidence, as causing probable serious effects to humans or the environment (e.g., endocrine disruptors).

SVHC are put on an authorization list and may not be placed on the market or used without special authorization. There are currently seven substances on the authorization list, and an additional 46 are being considered for inclusion.

While governments differ regarding definitions and approaches, they share a determination to identify and deal with chemical substances that pose an unacceptable risk to health or the environment.

Hazard and Risk

Two of the most important considerations when identifying toxic substances are the distinct yet interrelated concepts of hazard and risk. These concepts have been defined in various ways. For the purposes of this primer, "hazard" refers to the likelihood that a substance will exert its toxic effect on human health or the environment. "Risk" takes into account potential hazards and the likelihood of exposure to those hazards. It is measured according to the probability of exposure and the severity of the potential consequences. Risk assessment is a key factor in deciding whether a chemical substance should be identified as toxic.

Explaining Risk Assessment

Risk assessment takes into account both potential hazards and the likelihood of exposure. It attempts to answer the following fundamental questions:

- What can happen and under what circumstances?
- What are the consequences?
- How likely are these consequences to occur?

Risk assessment is an important decision-making tool that combines scientific evidence on health and environmental impacts with data about exposure (or models when data are lacking). When data are insufficient or incomplete, expert opinion is often sought. Risk management, which compares the relative risks posed by different management options, is based on risk assessment, and ensures that the course chosen is the one with the least potential for harm to human health and the environment.

Some feel that the application of risk assessment, though evolving, has some crucial limitations. For example, the process often isolates one substance, although we interact with many substances simultaneously in our daily lives. It must also take into account the intricacies of human development. As a result, risk assessment is often a lengthy process, sometimes taking several years.

The ability to identify toxic substances allows us to take preventive measures. In some cases, however, the evidence of harmful effects is not conclusive. To further complicate the issue, toxic substances usually occur in the environment not in isolation but in combination with many other substances (sometimes referred to as "complex mixtures"). Also, not all toxic effects are immediate; for example, certain cancers may occur only after years of exposure to low levels of a substance. For these reasons, it is difficult to identify which toxic substance is responsible for an effect or determine the most effective means of preventing exposure.

The Precautionary Principle

Opinions differ on the definition of the precautionary principle and its means of implementation. CEPA 1999 includes the most widely cited definition of the precautionary principle, formulated during the Rio Earth Summit in 1992: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Many health and environmental groups in Canada and other countries have challenged this definition. An alternative definition of the precautionary principle was developed during the Wingspread Conference on Implementing the Precautionary Principle: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." There are many differences between the two definitions, particularly with regard to the "duty to act" implicit in the Wingspread definition. These differences are important and have led to an ongoing debate about the use of the precautionary principle in Canada.

Regarding toxic substances, the precautionary principle can be applied to substances whose effects are uncertain but which may carry the risk of significant harm to human health or the environment. Many feel that CEPA 1999 is an adequate expression of the precautionary principle at work. Others hold that the precautionary principle plays a necessary role beyond the CEPA process because the number of new substances requiring assessment and the need to consider specific situations, such as the exposure of children, may hold up the assessment process significantly.

As new information about toxic substances continues to emerge, debates about the definition and interpretation of the precautionary principle are sure to continue.

For more information on the precautionary principle, see Pollution Probe's Applying the Precautionary Principle to Standard Setting for Toxic Substances in Canada at **http://www.pollutionprobe.org/old_files/Reports/precautionary.pdf**

What Are the Main Criteria for Identifying Toxic Substances?

As mentioned previously, the various definitions of toxic substances take into account a number of factors, including but not limited to the following:

- **hazard:** the degree to which a substance can be harmful to humans or animals, or the kinds of health effects it can cause
- **exposure:**

  persistence and bioaccumulative effects – some substances remain in the environment much longer than others, and some accumulate in the bodies of plants and animals.

  nature of exposure – the route of exposure (inhalation, ingestion or absorption), as well as its magnitude, duration, frequency and timing, contribute to toxic effects.

  likelihood of exposure – some substances have a greater potential for causing toxic effects because of increased likelihood of exposure.

Once the data on a chemical substance are compiled, an evaluation is made as to whether it should be considered a toxic substance according to the criteria established under the prevailing law. It is important to bear in mind that even when a substance is not officially declared toxic according to the relevant legislation, it is not necessarily without risk.

Hazard

When discussing the health effects of toxic substances, two terms are often used interchangeably: “hazard” and “toxicity.” In fact, these two concepts are quite different. As noted, “hazard” refers to the likelihood that a chemical substance will exert a toxic effect or cause harm to human health or the environment. “Toxicity” refers to an inherent property of a chemical substance. It is the ability of the substance to cause a harmful health effect. To determine whether a chemical substance is a hazard, it is essential to measure its potential toxicity.

MEASURING TOXICITY

Toxicity is measured during the pre-market evaluation of new products in order to identify potential risks to human health and the environment. New test methods are constantly in development to provide improved assessment of potentially toxic substances. These innovations are undertaken to improve test efficiency (reduction in time and expense), to understand more fully toxicity end points (the points at which health effects, such as developmental toxicity or endocrine disruption, are observed), and to replace, reduce and refine the use of animals in testing. Whenever possible, prediction based on previous experience and modelling is used in order to avoid unnecessary testing and eliminate nonviable approaches early in the development phase.

In general, knowledge of toxicity is obtained in three ways:

- through experimental studies using laboratory animals or cells (human, animal or plant)
- through the study and observation of humans during the normal use of a substance, after accidental exposure or by means of epidemiological studies
- through observation of wildlife (to evaluate environmental risk)

Not all of the tests used by regulators to measure toxicity are required by law. For example, tests for health end points such as developmental neurotoxicity and endocrine disruption are not currently part of required testing under legislation. Where data are not readily available, regulators may review studies from other jurisdictions and share information across levels of government.

Studies Using Animals or Cells

Assessment of the potential toxicity of a substance sometimes involves tests of laboratory animals, plants, micro-organisms or tissue cultures, or the use of models that predict animal or plant response. Standardized tests on animals have been developed for a variety of effects, including acute toxicity, chronic toxicity, carcinogenicity, reproductive toxicity, developmental toxicity and neurotoxicity (see Chapter Two for more information on these effects). Scientists are regularly devising alternatives to animal testing. One such alternative is a bacterial test using salmonella that evaluates a substance's ability to mutate DNA.

To determine the impact of a substance on humans, the level of toxicity is estimated based on test results derived from other mammals, including rats and mice. When the data are interpreted for humans, it is necessary to make allowances for greater or less susceptibility. There are many factors that account for the uncertainty of a toxicological database for humans, including the increased vulnerability of children and other determinants of health (see Chapter Two).

COMPARING TOXICITY

The measure of a dose at which 50 per cent of a test population dies (lethal dose, 50 per cent or LD_{50}) is used as a benchmark. The values for LD_{50} vary considerably among substances. When values for LD_{50} are being compared, a lower number indicates that the substance is more toxic (i.e., a small amount has a significant effect). Table 1-1 lists the LD_{50} of a few chemical substances (most, naturally occurring) based on the testing of laboratory rodents. The substance with the highest toxicity listed is botulinum toxin, a substance associated with botulism and the cosmetic and therapeutic treatment known as Botox®.

Table 1-1: Approximate LD_{50} of Some Representative Substances

Substance	LD_{50} (milligrams/kilogram of body weight)
Botulinum toxin (botulism, botox)	0.00001
Hemicholinium-3 (laboratory chemical)	0.2
d-Tubocurarine (anaesthetic)	0.5
Nicotine (cigarettes, tobacco)	1
Ethylene glycol (antifreeze)	50
Morphine sulphate (pain medication)	900
Ferrous sulphate (fertilizer)	1,500
Sodium chloride (table salt)	4,000
Ethyl alcohol (alcoholic beverages)	10,000

More toxic ↑

Klaassen, *Casarett & Doull's Toxicology: The Basic Science of Poisons*, (5th ed.), 1996, p. 14.

Occupational Exposure and Epidemiological Evidence

Toxicity can be measured by studying humans, using data compiled from occupational exposures or accidents and epidemiological evidence (the study of patterns of health, illness and associated factors at the population level). Ideally, epidemiological studies compare two groups of people who are alike except for one factor, such as exposure to a specific chemical or the presence of a health effect.

There are four main types of epidemiological studies:

- **cohort studies** – a group of individuals who have been exposed to a substance and a group who have not been exposed are followed over time to determine the incidence of health effects.
- **case control studies** – subjects are identified as cases (those who have the disease) or controls (those who do not have the disease) and their exposure histories are compared. For example, individuals with cancer are compared to similar individuals without cancer to determine any associations with their history of exposure.
- **cross-sectional studies** – the relationship between exposure and health effects in a defined population (e.g., the prevalence of respiratory conditions among furniture makers) is examined at a single point in time.
- **ecological studies** – the relationship between exposure and health effects is examined at the population, rather than the individual, level. The incidence of a disease in one geographical area is compared to that of another geographical area (e.g., cancer rates in areas with hazardous waste sites and in areas without waste sites).

There are a number of conditions that must be considered when designing an epidemiological study, including appropriate controls, adequate time span and statistical ability to detect an effect. The control group must be as similar as possible to the test group (ideally, the same age, sex, race, social status, geographical area, and environmental and lifestyle influences). Statistical models are then used to determine if exposure to the substance in question is associated with the health effect.

Studies Using Wildlife

To determine the impact of a toxic substance on the environment, most studies observe wildlife (primarily birds and fish), as well as other susceptible species (e.g., honeybees, earthworms and water fleas). Wildlife studies include data gathered from wildlife that have experienced typical exposures to toxic substances and those that have been exposed to high levels from contaminated areas. To ensure broad environmental protection, these studies cover a range of species, with the most sensitive species often acting as the basis for regulatory decisions on permitted releases.

THRESHOLD OF TOXICITY

It would be easy to assume that lower doses of a chemical substance are less harmful than higher doses. While this is generally true, some substances exhibit different patterns of toxic effects because of variations in the response of organisms.

- The most common dose pattern is referred to as a "threshold." This applies to substances that have a specific dose (or concentration) below which no harmful effect is expected to occur. Above the threshold, there is risk of adverse effects. Ammonia is an example of a substance with a threshold.
- Some chemicals have no threshold. This is the case with many carcinogens, such as benzidene, which has been used primarily as an intermediate in the manufacture of dyes and pigments. Benzidine is not produced in Canada and its use is restricted.
- Other chemical substances exhibit a U-shaped pattern of effects. These substances can cause a harmful effect at a low dose, little or no effect at a medium dose and a different harmful effect at a high dose.

It is worth noting that there is no general consensus about the validity of these dose patterns. For example, some argue that there are no chemical substances without a threshold.

ACUTE OR CHRONIC TOXICITY

Toxic effects are generally characterized as acute or chronic. Most chemical substances have acute and chronic thresholds. The former is typically higher than the latter. "Acute toxicity" refers to the adverse effects of a substance as a result of one or a few brief exposures over a short period of time (usually less than 24 hours). The resulting health effects can range from skin irritation to coma or even death. "Chronic toxicity" refers to the adverse effects of a substance as a result of continuous or repeated low-dose exposures over the long term. While an individual exposure to a toxic substance may not be serious in itself, cumulative exposure over a long period can lead to harmful effects in humans, including cancer or nervous system damage.

TARGETS FOR TOXIC EFFECTS

Toxic substances affect living organisms through various mechanisms. Their effects vary from one species to another according to each species' genetic makeup and ability to detoxify (remove or expel toxic substances). For example, dioxin is highly toxic to guinea pigs but only slightly toxic to hamsters.

Some toxic substances target specific tissues or organs. Neurotoxicants, for example, affect the brain and nervous system. Others may act on many parts of the body at the same time. When dealing with a number of targets, regulators look for the one that is the most sensitive, referred to as the "critical effect." The assumption is that standards based on the critical effect will also protect less sensitive targets. The effects of toxic substances on human health and the environment will be discussed further in Chapters Two and Three.

Lead – An Example of a Non-threshold Substance

Lead is a naturally occurring substance and one with many industrial uses because it is durable, flexible, easy to melt and form, and remains relatively inexpensive. Low levels of lead are found in food, drinking water, household dust, soil and some consumer products such as costume jewellery, art supplies, and candles. Lead can also be found in paint predating 1978 and, in trace amounts, in some types of paint available today. Proper precautions should be taken when renovating a home that may have lead paint.

Lead was widely used until its toxic effects became better known in the latter half of the twentieth century. Its use as an "octane enhancer" in gasoline continued into the early 1990s, at which point it was banned from automotive gasoline. Before the ban, lead in the air was the main source of exposure for Canadians. Levels of lead found in the environment have continued to decline significantly.

Lead has the potential to enter our water supply through lead pipes and lead solder in the plumbing of homes built before 1950. The amount of lead that can leach into drinking water increases as water sits in pipes. Many municipalities have instituted programs to replace lead service lines. To find out if your home's water is supplied by a lead service line, contact your municipality.

Recent scientific studies on lead show that adverse health effects are occurring at levels of exposure lower than those previously assumed to have such effects. At low levels of exposure, the main health effects observed occur in the workings of the nervous system; specifically, exposure to lead may have subtle effects on the intellectual development of infants and children. Children and fetuses absorb lead more readily than adults and are, therefore, particularly vulnerable to its potential health effects. Pregnant women may also pass lead in their blood to their fetus.

Lead was one of the first substances in Canada to be included in the List of Toxic Substances. Federal legislation addresses the main sources of lead exposure. Ontario's regulations regarding lead include the Ontario Air Standards for Lead and Lead Compounds, *Ontario Safe Drinking Water Act* and brownfields regulations.

For more information on the health effects associated with exposure to lead, see **http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/lead-plomb-eng.php**

Exposure

PERSISTENCE AND BIOACCUMULATIVE EFFECTS

Other determinants of toxicity used by regulators are persistence in the environment and bioaccumulative effects. Both can dramatically increase potential exposure to a chemical substance.

Persistence in the Environment

Some chemical substances quickly break down or transform into other substances when released into air, water or soil. These new substances can be more or less harmful than the original substance. Other chemical substances do not break down or transform easily in the environment – these are known as persistent chemical substances. Once they are released into the environment, they are available for uptake by organisms for a long period of time, sometimes decades. As a result, the likelihood and duration of exposure to these substances are significantly greater. Substances that are toxic and persistent pose a particular challenge for remediation and, in many cases, become legacy problems. Once these chemical substances are in the environment, simply reducing current emissions will not eliminate the environmental risk. Although PCBs have not been sold in Canada for more than twenty years, there are still places contaminated by them because they break down so slowly.

PCBs – An Example of a Persistent Substance

Polychlorinated biphenyls, or PCBs, were commonly used in electrical equipment and in the manufacture of heat exchangers, hydraulic systems and other applications until the late 1970s. These synthetic substances were designed to be strongly resistant to degradation and to have excellent insulating and thermal properties. As a result, they do not biodegrade or decompose significantly in the environment. Signs of environmental harm caused by PCBs were first seen in fish and wildlife species in large aquatic ecosystems, such as the Great Lakes, where PCB contamination persists today. While PCBs were never manufactured in Canada, they were widely used. In 1977, they were banned from import, manufacture and sale, and in 1985, their use was made illegal.

The most obvious signs of environmental harm caused by PCBs have been observed in aquatic ecosystems and in species whose diets consist primarily of aquatic organisms. Most of the evidence we have today of the effects of PCBs is based on observations of people who have been briefly exposed to high levels of PCBs on a job site or as a result of an accident. PCBs are persistent, bioaccumulative and inherently toxic, and are classified as toxic under CEPA 1999.

Phthalates

Phthalates are a diverse group of chemicals mainly used to soften plastic, including vinyl. Phthalates have a wide range of industrial and consumer applications. Some types are found in children's products, medical equipment, flooring, packaging, paints and lubricants. The toxicity of phthalates is not fully understood; while many are considered safe for use, the effects vary by type. Research has shown, however, that a small number of phthalates may be linked to reproductive and developmental toxicity, and liver and kidney effects in rodents.

Phthalates are "fat-loving" and have the potential to migrate from plastic into fatty foods. Exposure to phthalates can occur through food in plastic packaging (especially fatty foods, fish and shellfish) and indoor air (where phthalates are released from plastic materials, coatings and flooring). It is not the presence of phthalates in consumer products in itself that constitutes a health risk but the possibility that they may leach out. Exposure for adults is often negligible; however, periods of sustained mouthing action (sucking or chewing) by children may allow phthalates to enter the body through the saliva.

In a precautionary response to evidence of health risks, the European Union directed its members to ban a small number of phthalates from children's toys by 2007. In Canada, the *Phthalates Regulations* under the *Canada Consumer Product Safety Act* (CCPSA) came into force in June 2011. The regulations restrict the advertising, sale and importation of toys and child-care articles made from soft vinyl containing any of the six phthalates listed in the regulation.

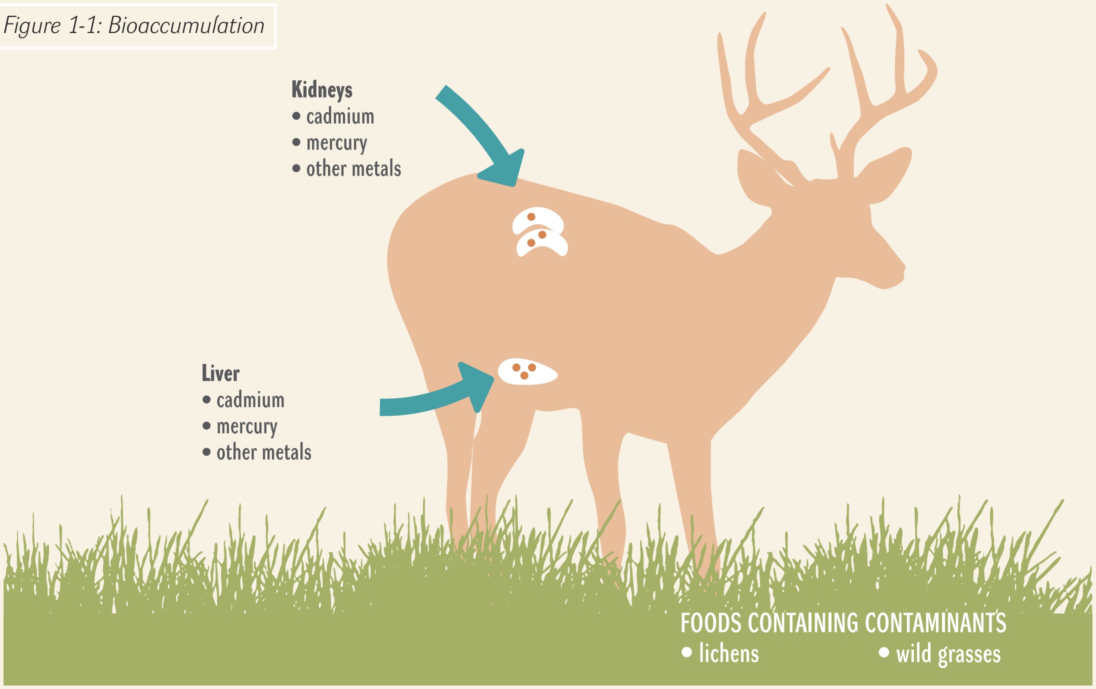
For more information on Canada's *Phthalates Regulations*, see **http://www.gazette.gc.ca/rp-pr/p1/2009/2009-06-20/html/reg3-eng.html**

Bioaccumulative Effects

Bioaccumulation occurs when living organisms take up a chemical substance more rapidly than they can eliminate it, so that the contaminant accumulates in their bodies. As a result of the bioaccumulation process, exposure to small, continuous doses can become a serious problem. While a chemical substance may not be toxic at low levels of exposure, it can reach toxic levels as it accumulates in an organism over time.

In some cases, accumulation of a toxic substance occurs in living organisms through contact with the surrounding environment other than through dietary intake. This phenomenon, known as bioconcentration, often occurs in aquatic environments and organisms. A toxic substance may concentrate in fish through their contact with water containing this substance. As a result of bioconcentration, levels of a toxic substance in an organism exceed those found in the surrounding environment.

Figure 1-1: Bioaccumulation



Adapted from Aboriginal Affairs and Northern Development Canada, 2011
Available at www.aadnc-aandc.gc.ca/eng/1100100023425

Chemical substances that bioaccumulate or bioconcentrate may also demonstrate biomagnification: that is, they become increasingly concentrated as they move up a food chain. For example, a bioaccumulative chemical substance present in a lake is absorbed by micro-organisms. Smaller fish regularly consume large quantities of these micro-organisms and, in turn, become prey for bigger wildlife and so on up the food chain. The concentration of the substance becomes higher in each link of the chain. As a result of biomagnification, concentrations of chemical substances can be several times higher in species at the top of the food chain. One substance that demonstrates both bioaccumulation and biomagnification is methylmercury.

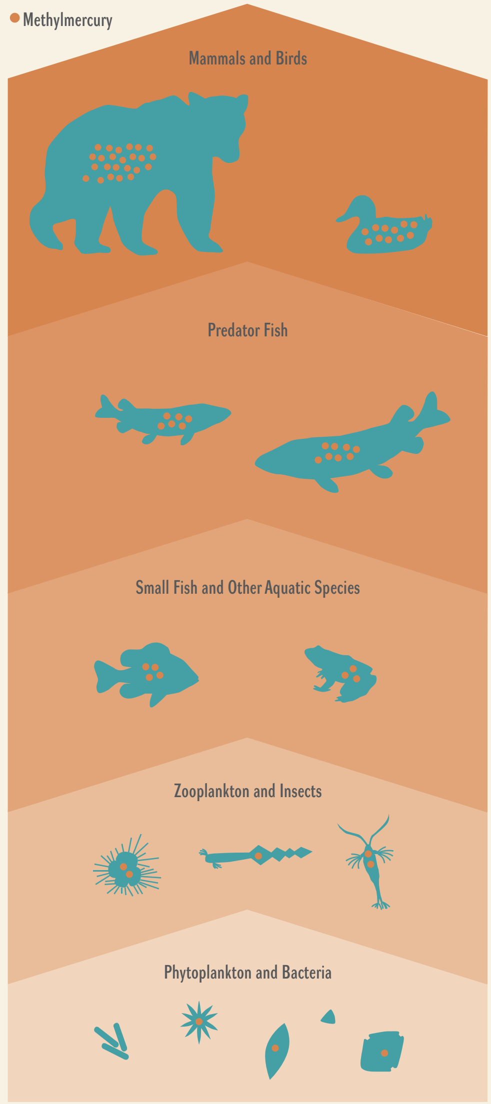
NATURE OF EXPOSURE

For a toxic effect to occur, a sufficient amount of a toxic substance must interact with an organism, reach its target organ or tissue and remain for the time it takes to cause damage. For some toxic substances, a single exposure is enough for a toxic effect: for others, prolonged exposure is required.

Some of the many factors that influence the exposure are

- dose or concentration of the substance during time of exposure
- route of exposure – whether it can reach target organs or tissues
- duration, frequency and timing of contact
- multiple exposures

Figure 1-2: Biomagnification of Methylmercury



Mercury – An Example of Biomagnification

Mercury is a heavy metal that is naturally present in the environment. It can be released naturally or through human activities such as the burning of coal. Like all heavy metals, mercury persists in the environment because it cannot be broken down. Bacteria can transform mercury found in sediment into methylmercury, which can bioaccumulate in animals and biomagnify. Methylmercury is the form of mercury to which humans are most often exposed, primarily through the consumption of fish. When mercury is released into the atmosphere, it can be transported long distances on wind currents, deposited back onto land or water and re-emitted into the atmosphere.

As a result of human activities, the mercury in some fish has risen to levels of concern for those who make fish a staple of their diet. These levels are a cause for caution on the part of pregnant women, as the developing fetus is particularly vulnerable to the effects of mercury. Mercury can interfere with the development of the brain and the nervous system. Control measures introduced in the 1970s and 80s contributed to significant reductions in mercury releases from key sectors. The phasing out of coal in some regions, including Ontario, will significantly reduce mercury emissions.

Under the auspices of the United Nations Environment Programme, discussions are now underway to establish a global, legally binding instrument on mercury.

Toronto Public Health publishes a list of fish that can be safely eaten frequently (even more than once a day) by pregnant women and children.

For more information, see *A Guide to Eating Fish for Women, Children and Families* at **http://www.toronto.ca/health/fishandmercury/pdf/guide_eat_fish.pdf**

Dose or Concentration

The dose or concentration of a chemical substance in the environment is one of the main factors in determining its potential for toxic impacts. Most often, a toxic effect occurs only if the concentration of the substance is at a sufficient level to do harm, that is, if the concentration of a chemical substance is higher than its threshold for toxicity. If the concentration of the substance is well below the threshold, it may be considered to be at a sufficiently low level in the environment, as long as other factors (e.g., persistence or bioaccumulation) are not involved. Of course, there are some substances that have an effect at very low levels, and some non-threshold substances that are considered toxic at any level. As more becomes known about the toxicity of substances, the current specifications for safe levels may change.

Route of Exposure

As noted, chemical substances, including toxic substances, often target certain organs or tissues in humans and other organisms. There are three main routes of exposure for chemical substances:

- absorption through the skin surface or other membranes
- inhalation (breathing)
- ingestion (eating or drinking)

Depending on the nature of the chemical substance, some routes of exposure are of more concern than others. For example, touching lead is not likely to be very harmful because it is poorly absorbed through the skin; however, ingesting or inhaling lead may result in serious harmful effects.

Further information on the risks associated with different routes of exposure will be presented in Chapter Two.

Duration, Frequency and Timing of Exposure

The duration and frequency of exposure can greatly influence the effects of a chemical substance. There are two relevant types of exposure: acute and chronic.

Acute exposure takes place during a short period of time (minutes, hours, one day). This type of exposure to chemicals such as tetrachloroethylene, a volatile organic compound (VOC) for use as a solvent in the dry-cleaning and metal-cleaning industries, can result in eye, nose and throat irritation, nervous system depression and unconsciousness. Tetrachloroethylene is no longer produced in Canada, but it continues to be imported.

Chronic exposure is continuous or repeated contact with a chemical substance for longer than three months. Some substances remain harmless despite chronic exposure, but others have harmful effects over time, even at low doses. For example, PCBs and lead can build up in the body over time and cause long-term health effects. The results of long-term exposure are more difficult to assess, as it can take years for toxic effects to become obvious.

The timing of exposure – the stage of life (fetus, child, adult) when exposure occurred – can also be crucial.

Multiple Exposures

Assessments of toxic substances are generally based on data from studies on individual substances. In our day-to-day lives, however, we are often simultaneously exposed to a number of substances through consumption, inhalation or other means of uptake. Cigarette smoke, for example, contains a mixture of several toxic substances, including cadmium, acetaldehyde and formaldehyde. Multiple exposures to various substances can have different toxic effects than exposure to an individual substance.

The combination of chemical substances can have three effects:

- **antagonism** – the combined effect of two chemicals is less than the sum of the effects of each chemical.
- **synergism** – the combined effect is greater than the sum of the effects of each chemical.
- **potentiation** – the toxicity of one chemical substance is enhanced when paired with another chemical that does not have toxic effects.

More work is still required to determine the effects of exposure to low doses of substances that are not of concern individually but may be so in combination. Data on human exposures to these mixtures are limited. As there are many possible combinations of chemical substances and comprehensive testing is not currently feasible, such exposures have not been fully addressed.

LIKELIHOOD OF EXPOSURE

Regulators consider factors that affect the likelihood of exposure in their assessments, including

- the amount of the substance released or found in a product
- the transport and fate of the substance in the environment

In the case of humans, determinants such as lifestyle and age can also significantly affect the likelihood of exposure. These are discussed further in Chapter Two.

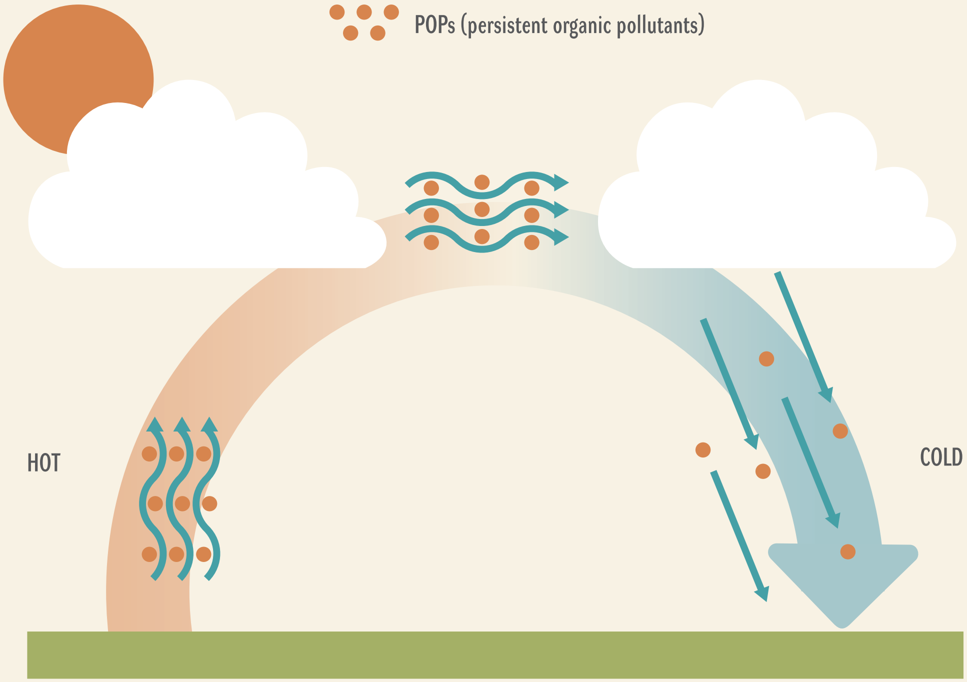
Amount of Toxic Substance Released

The amount of a toxic substance released influences the likelihood of exposure for organisms and people. Toxic substances can be released from an industrial source or at any point in the life cycle of a product, from extraction and production processes to transportation, consumer usage and disposal.

Transport and Fate

Once a chemical or toxic substance is released, it is transported through, and interacts with, the receiving environment. During its course, it may bind to particles or other materials, or be transformed through natural processes into a different substance. The newly formed substance may be more or less toxic than the original substance and more or less available for uptake by living organisms. The transport and fate of a toxic substance can, therefore, influence the likelihood of exposure and toxic effects. Some chemical substances travel considerable distances via the atmosphere or water systems, reaching environments very remote from their point of release. Persistent organic pollutants (POPs), for example, are organic compounds that, due to their persistence in the environment, bioaccumulate in humans and animals, and travel long distances to regions where they have never been produced. These substances are identified in international agreements as priorities for global management because controls at source are considered insufficient.

Figure 1-3: Transport and Fate – The Transboundary Movement of Persistent Organic Pollutants (POPs)



1. In warm temperatures, POPs evaporate.
2. POPs are carried by the wind to colder places such as the North.
3. In cold temperatures, POPs condense and fall to earth.

Adapted from Aboriginal Affairs and Northern Development Canada, 2011 Available at **www.aadnc-aandc.gc.ca/eng/1100100023383**

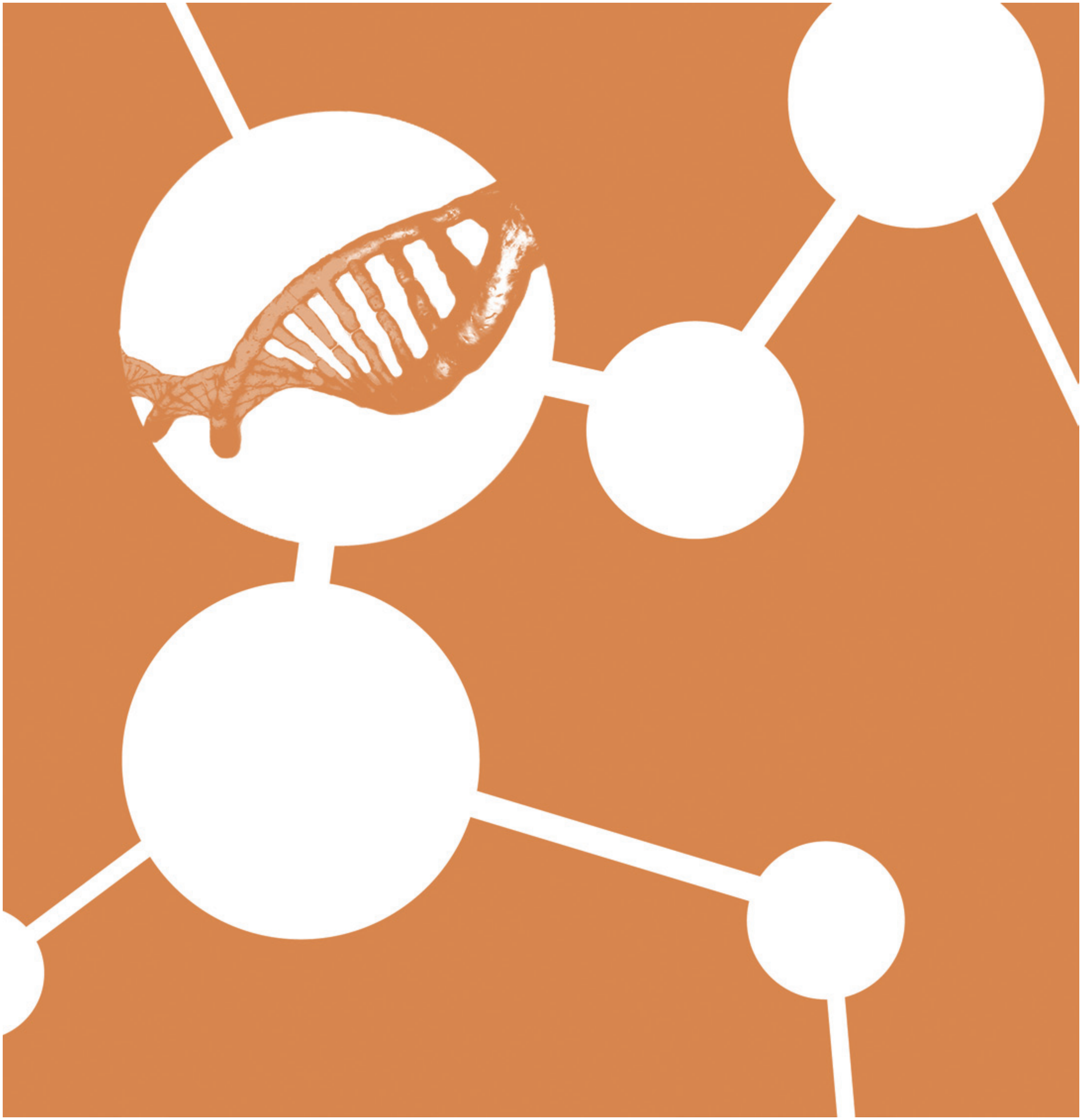
Challenges Ahead

The Canadian government receives approximately 525 applications for the use of new chemical substances every year. Each requires a risk assessment by industry and the government. Substances that demonstrate high levels of toxicity, combined with persistence and bioaccumulative effects, are prioritized. Our understanding of the toxic effects of chemical substances is continually evolving; regulators are required to maintain up-to-date knowledge of the research in their field.

Both government and industry have undertaken measures to hasten the identification of the chemical substances that have a high risk of harmful effects. Industry is obligated under Canadian law to notify the government if it has data indicating that a substance is toxic (Section 70 of CEPA 1999). Of the thousands of chemical substances that have been assessed, only a few have been defined as toxic substances. Thorough assessments of substances, and particularly of combinations of substances, will take many years.

Summary

This chapter outlined some of the many criteria considered by various jurisdictions when they are identifying and assessing toxic substances. Assessment is an important step in determining a suitable management strategy for a toxic substance. Hazard, toxicity and exposure are key concepts when considering the human health effects of toxic substances. They will help us address the question posed in the next chapter: "How can toxic substances affect me?"



Chapter Two

WHAT ARE THE IMPACTS ON HUMAN HEALTH?

Exposure to BPA may be greater than previously thought – Toronto Star, June 6, 2011

This chapter focuses on some of the effects resulting from exposure to toxic substances. After reading this chapter, you should have a better understanding of potential effects, based on the route, timing and duration of exposure discussed in the previous chapter.

An exhaustive examination of the human health effects of toxic substances is beyond the scope of this primer. This chapter provides a brief summary of the current understanding of a few of these effects. For a more comprehensive treatment of this subject, see the Selected References and Useful Websites section of this primer.

The Determinants of Health

The health of an individual is the result of a complex interaction of factors over a lifetime, sometimes referred to as "the determinants of health." Individuals do not have control over many conditions that contribute to their overall health, such as genetics, gender or their environment. Some determinants of health may be related to our behaviour (e.g., smoking) or the products we use.

Social, economic and environmental factors underlie many behaviours that affect our health. The World Health Organization defines "social determinants of health" as the "conditions in which people are born, grow, live, work, and age, including the health system." These social determinants contribute to disparities between the health of those with resources and those without.

Figure 2-1: Determinants of Health

Adapted from World Health Organization website.
Available at http://www.who.int/hia/evidence/doh/en/

The Body's Protective Functions

The human body performs various protective functions, including the detoxification and elimination of toxic substances. The respiratory system eliminates inhaled foreign matter, and the liver detoxifies many contaminants. The immune system works to prevent disease.

While these mechanisms are very effective in eliminating many toxic substances from the body, they cannot always prevent some effects. These vary from substance to substance and within species of organisms. Children and fetuses have physical systems that are in the process of development, so they are particularly vulnerable to toxic substances. A child's skin is more permeable than an adult's, allowing substances to pass easily into the bloodstream. People who are older, who have a compromised immune system or who are nutritionally deprived are also more vulnerable.

Types of Health Effects

There are several types of effects that have been associated with exposure to toxic substances. They range from temporary and relatively mild to chronic and serious, and include, but are not limited to, those

- causing or contributing to cancer (carcinogens)
- damaging reproductive tissues or the normal development of a fetus, infant or child (reproductive or developmental toxicants)
- damaging the normal development and function of the brain and nervous system (neurotoxicants)
- interfering with normal hormone production and function (endocrine disruptors)
- interfering with the immune system (immunotoxicants)
- contributing to respiratory diseases (respiratory toxicants)
- causing adverse effects on the cardiovascular or blood system (cardiovascular and blood toxicants)
- causing liver or gastrointestinal damage (gastrointestinal toxicants)
- damaging the kidney, ureter or bladder (kidney toxicants)
- contributing to bone disorders including arthritis (musculoskeletal toxicants)
- contributing to skin diseases or damaging sense organs (skin or sense organ toxicants)
- causing multiple health effects

While infrequent, accidental releases resulting in acute effects can occur, and, in general, these effects are well understood. Most exposures for the general public, however, are low-dose chronic exposures, and some of their effects remain uncharted. It is beyond the scope of this primer to address all known and suspected health effects in detail. The following sections provide a brief overview of a small number, which include well-established examples (e.g., carcinogens, reproductive toxicants) and those that are the subject of evolving research because of limited data on humans (e.g., endocrine disruptors).

Formaldehyde – An Example of a Human Carcinogen

Formaldehyde, a volatile organic compound (VOC), is a flammable, colourless substance that is found in building materials and household products. It is used in pressed-wood products (e.g., plywood), glues and adhesives, paper product coatings, insulation and fabrics. It is also commonly used as an industrial fungicide and disinfectant, and as a preservative in medical laboratories. Releases occur as a result of industrial use and fuel combustion. Formaldehyde also occurs naturally in the environment and can be released through occurrences such as forest fires.

Symptoms of acute exposure to formaldehyde include coughing, wheezing, nausea, skin irritation, and burning sensations in the eyes, nose and throat. Long-term exposure has been linked to cancer. Following Hurricane Katrina, residents temporarily housed in trailers began to experience acute and severe respiratory problems. Their symptoms were eventually linked to unusually high levels of formaldehyde found in the glue used to bind together the particleboard, fibreboard and plywood of the trailer's cabinetry and furniture.

Formaldehyde is considered to be a human carcinogen by the International Agency for Research on Cancer and a probable human carcinogen by the US Environmental Protection Agency.

For a more detailed understanding of these and other health effects, see Health Canada's "It's Your Health" website at **http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/alpha-eng.php**

For a more specific discussion of the effects on children, see *Children's Health and the Environment – A Primer* at **www.healthyenvironmentforkids.ca**

Carcinogens

Chemical substances, including toxic substances, that may contribute to cancer are referred to as "carcinogens." Cancer is a condition of abnormal cell growth, unregulated by normal mechanisms in the body. There are a number of types of cancer, each with its own set of factors, which can include genetics, age, natural mutations or exposure to certain chemical substances. The percentage of cancers caused by exposure to toxic substances has not been determined.

Chemical substances are evaluated for carcinogenicity by a number of agencies. The International Agency for Research on Cancer (IARC) has classified more than 400 agents as known carcinogens (sufficient evidence in humans), probable carcinogens (limited evidence in humans and sufficient evidence in experimental animals), possible carcinogens (limited evidence in humans and less than sufficient evidence in experimental animals) or non-carcinogens (inadequate or limited evidence in humans or animals). Most of the substances evaluated by the IARC are connected only to certain types of cancer, and the list does not address the likelihood of these substances causing cancer. Even known carcinogens do not cause cancer at all times, under all circumstances. Some may be carcinogenic only through a specific route of exposure or after a certain length of exposure. The IARC criteria take into account environmental factors that can increase the potential for cancer, including chemicals, complex mixtures, biological agents, occupational exposures and lifestyle factors. Asbestos, benzene and cadmium are examples of toxic substances considered known carcinogens by the IARC.

For more information related to carcinogens, see the IARC website: **http://monographs.iarc.fr/ENG/Classification/index.php**

IARC Criteria for Assessing Cancer Causation Due to Environmental Exposures

- The link between the exposure and cancer is strong.
- The risk of cancer increases with more exposure to the agent.
- Studies by various investigators with a wide range of sample groups yield the same finding.
- Exposure to the agent predated the cancer.
- There is a plausible biological explanation of the way in which the agent could cause cancer.
- The link is specific, and the agent causes a specific type of cancer.
- The link is consistent with what is known from other studies.

POSSIBLE MECHANISMS OF CANCER DEVELOPMENT

Exposure to toxic substances may alter or interfere with a variety of biological processes. One way in which exposure can lead to cancer is by damage to the DNA, affecting a cell's normal process. Errors commonly occur during normal cell division, but cells have mechanisms to correct errors, including DNA repair and self-destruction. Damaged DNA can result in more frequent cell replication and impaired ability to correct errors, leading, in turn, to gene mutations that can cause cancer to develop. If such damage occurs in reproductive cells, mutations may be passed on to future generations.

Genes are fundamental to biological processes, including normal cell growth and cell death. They direct the initiation, operation and cessation of biological processes. Exposure to some toxic substances can suppress the genes that control the cell growth of tumours.

Inflammation can also increase the likelihood of a number of diseases, including cancer. Inflammation of the lung tissue caused, for example, by the inhalation of asbestos fibres, tobacco smoke or fine particulate matter in the air is often a major factor in lung and other respiratory tract cancers.

Benzene – An Example of a Reproductive and Developmental Toxicant

Benzene is a common VOC that presents as a clear, colourless liquid with a strong, sweet odour. It is flammable and occurs naturally in crude petroleum. Benzene can be found in some transportation fuels, though the amount is strictly limited by regulation in Canada. It is present in cigarette smoke and can also enter the environment through solvent use, residential fuel combustion, gasoline marketing, and the production processes for benzene, other chemicals, and iron and steel.

Benzene is known to cause reproductive and developmental effects, including reduced fetal weight, fetal chromosomal damage and alterations to sperm. Some studies have implicated benzene in the development of childhood leukemia through in utero exposure or paternal exposure before conception. However, other studies do not support this association. Benzene is a known human carcinogen. Short-term exposure may cause depression of the central nervous system, marked by drowsiness, dizziness, headache, nausea, loss of coordination, confusion and unconsciousness. Benzene is considered toxic under CEPA 1999.

For more information on benzene, see Pollution Probe's *Primer on Volatile Organic Compounds* at www.pollutionprobe.org/Publications/Primers.html

Toxic substances may also affect the production and function of hormones, which are crucial to human growth and the maintenance of many biological processes. Some toxic substances can mimic estrogen in the human body. When exposure occurs early in life, it may contribute to early puberty and, therefore, a longer period of exposure to estrogen throughout a lifetime. Long-term exposure to estrogen has been linked to an increased risk of some types of cancer, including breast cancer.

Reproductive or Developmental Toxicants

Toxic substances that have adverse effects on the ability to reproduce are called reproductive toxicants, and those that affect the developing fetus or child have been labelled developmental toxicants.

Reproductive issues in both men and women can result from exposure to toxic substances experienced in the womb, in childhood or in adulthood. Reproductive toxicity may result in miscarriage or a decrease in fertility. Some evidence suggests that the partners of men whose occupation involves exposure to vinyl chloride have increased rates of spontaneous abortion. Though the connection is not fully understood, some believe that vinyl chloride interferes with sperm function.

Developmental toxicity of the fetus or child can result from prenatal exposures to toxic substances through the mother or father. Effects include low birth weight and biological dysfunctions and behavioural issues that may manifest themselves as the child grows.

Reproductive and developmental effects are not an inevitable outcome of exposure to these toxicants. Again, a number of complex factors must be taken into consideration, including the timing of exposure. A toxic substance that is capable of causing a developmental effect during early pregnancy may not have the same effect later in the pregnancy.

Neurotoxicants

Chemical substances that damage the brain and nervous system are known as neurotoxicants, and those affecting the development of the brain are called developmental neurotoxicants. Both neurotoxicants and developmental neurotoxicants are believed to affect motor activities, emotional states, behaviour and learning capabilities. Sensory systems may also be affected, including sight, hearing, touch and pain. Methylmercury is one example of a neurotoxicant known to cause damage to the visual, sensory and motor systems.

Existing health issues may increase the risks associated with neurotoxicants. For persons suffering from neurological disorders such as multiple sclerosis, these substances may exacerbate existing problems.

The developing brain is inherently more vulnerable than the adult brain to the damage that can be caused by some toxic substances. As a result, effects seen in an adult brain may be observed at much lower exposures in a developing brain. Chronic exposure to some developmental neurotoxicants has been linked to learning and developmental disabilities in children, including autism spectrum disorders, attention deficit hyperactivity disorder, and vision and hearing problems. Further research is needed to understand the nature of these links.

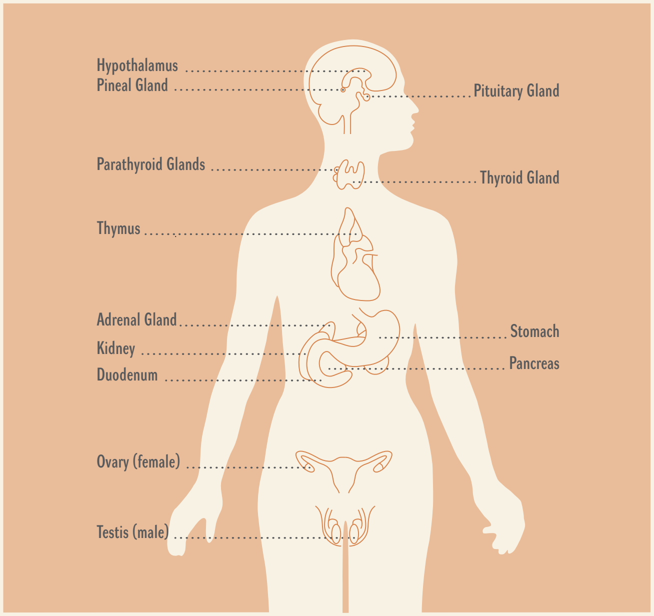
At the other end of the spectrum, the elderly are also more susceptible to the effects of some neurotoxicants. Adverse effects that may have been masked at a younger age by a healthy nervous system can become more apparent later in life.

The Minamata Tragedy

The hazards of methylmercury poisoning received international attention in 1956 when many of the residents of Minamata, Japan, died or became severely ill after eating the fish and shellfish in Minamata Bay. A manufacturing facility was disposing of methylmercury-contaminated wastes directly into the bay. This mercury accumulated in the fish and shellfish, which were a staple of the residents' diet. The Minamata tragedy drew attention to links between mercury discharges and its bioaccumulation in the environment.

Cats in Minamata were the first to show signs of mercury poisoning. Due to their uncontrollable muscle spasms and tremors, the disease was initially referred to as "cat dancing disease." The people of Minamata eventually began to exhibit similar symptoms. The physiological effects, including loss of motor control and even partial paralysis, were devastating. Residents had difficulty walking, writing, hearing and swallowing, and experienced uncontrollable trembling. Further research on the area's cats led scientists to conclude that mercury contamination was the cause. Unfortunately for the people of Minamata, government officials waited nearly ten years before accepting the evidence, leaving thousands more to suffer. Today, much of Minamata Bay has been filled in with clean soil, and local residents are again permitted to eat the fish.

Figure 2-2: The Endocrine System



Endocrine Disruptors

The endocrine system is a complex network of hormone-producing glands. The pituitary gland, thyroid gland, adrenal gland, thymus, pancreas, ovaries and testes release hormones into the bloodstream that act as natural chemical messengers, travelling to various parts of the body to control and adjust many functions. Other organs, including the kidney, liver, and heart, have secondary endocrine functions. The endocrine system is instrumental in regulating mood, growth and development, tissue function, metabolism and reproductive processes.

Endocrine disruptors can interfere with the hormonal communications between cells. They can mimic hormones, block hormones, and otherwise affect the production, transport and removal of hormones. Toxic substances suspected of being endocrine disruptors include PCBs, dioxins and some phthalates.

Identifying direct links between exposure to endocrine disruptors and human health effects is difficult, and human evidence to date is relatively limited and poorly understood. Effects have been reported in mollusks, crustaceans, fish, reptiles, birds and mammals.

Because endocrine disruptors affect the development of the body's vital organs and hormonal systems, children and fetuses are particularly vulnerable to exposure. Fetuses can be exposed through placental transfer, and newborns through breastfeeding.

For more information on endocrine disruptors, see the Endocrine Society website **http://www.endo-society.org/**

Immunotoxicants

The immune system – a complex network of organs, tissues and cells – defends the body against invaders such as disease and bacteria. When it identifies foreign substances, the immune system uses enzymes, white blood cells, chemicals and proteins to attack them. An impaired immune system either under-reacts and fails to fight infection or overreacts and forms antibodies to combat substances that are not necessarily toxic. It is believed that one of the ways in which toxic substances can affect the immune system is by compromising its ability to identify foreign substances. The effects of toxic substances on the immune system are difficult to isolate because they can cause a variety of complicated responses. Exposure to some toxic substances, including asbestos, benzene, PCBs and dioxins, has been linked to immunosuppression (where the body's immune response is reduced or depleted) in humans. Other toxic substances are believed to cause autoimmune diseases in which healthy tissue is attacked when mistakenly identified as a foreign substance. Animal research has linked bisphenol A (BPA) exposure to compromises in the development of the immune system and to a greater likelihood of asthma. A damaged immune system can increase vulnerability to other serious conditions, including cancer, as it is unable to respond adequately to invading agents.

Asbestos – An Example of a Toxic Substance Linked to Immunosuppression

Asbestos is composed of six naturally occurring minerals that are incombustible and separate into filaments. Chrysotile, the only form of asbestos extracted in Canada, is believed to be the least dangerous to human health. Most people know that asbestos was used as insulation in houses and buildings, but few are aware of its wide use in construction and building materials such as fire-retardant products. When asbestos-containing materials are disturbed or damaged by repair, remodelling or demolition activities, fibres can become airborne and be inhaled into the lungs, where they can cause significant health issues.

Exposure to asbestos can increase the risk of lung diseases such as asbestosis and lung cancer. Smoking has been linked to an increased risk of illness related to asbestos exposure. People exposed to asbestos are usually employed in industries that mine, produce or use asbestos products (e.g., construction, textile industries, automotive repairs).

ASTHMA AND OTHER RESPIRATORY EFFECTS

Asthma is a chronic disease of the lungs and airways characterized by periodic acute episodes (asthma attacks). During these attacks, airway linings become inflamed, swollen and partially blocked, causing coughing, wheezing and breathing difficulties. Asthma and other respiratory effects, including allergies, are often the result of an overactive immune system that has developed an exaggerated response to certain foreign substances or allergens.

There is strong evidence that indoor and outdoor air pollution, which may include toxic substances, aggravates asthma and other already existing respiratory ailments. Children are particularly sensitive to these exposures.

For more in-depth information about asthma and other respiratory effects, see The Lung Association's website at **www.lung.ca**

Multiple Health Effects

Analyses of the health effects of toxic substances often assume an interaction between a single chemical and a particular organ or type of tissue. In fact, people can be exposed to multiple toxic substances throughout the day, and exposure to even one substance has been linked to a variety of concurrent health effects. Lead, methylmercury, PCBs, dioxins and furans are each believed to cause multiple health effects.

The study of multiple health effects is in its early stages. Lack of consensus has led to controversy about the appropriateness of certain precautions. The study of multiple effects associated with air pollution is one field that has generated conclusive data. Toxic substances found in air pollution have been linked to asthma, respiratory effects, and developmental effects including reduced birth weight in babies and some cardiac birth defects.

Multiple health effects present a significant challenge for regulating agencies. There is currently insufficient evidence to link many suspected causes of multiple health effects to specific exposures.

Biomonitoring

"Body burden" refers to the toxic substances (or their breakdown products) that we carry in our bodies. Biomonitoring measures this burden in human blood, urine, hair, saliva and breast milk at a particular point in time. The detection of a chemical substance does not necessarily entail an adverse human health effect. Gaining more exact measurements of exposure is necessary.

Recently, the Government of Canada has conducted surveys to provide nationally representative data on the health of Canadians. The Canadian Health Measures Survey includes a toxic biomonitoring component, which measures 91 chemical substances or substance groups in the blood and urine. Health Canada has undertaken research into more effective use of biomonitoring data and supports biomonitoring initiatives in targeted populations, such as the Maternal-Infant Research on Environmental Chemicals Study, which measures chemical substances in pregnant women.

Biomonitoring is still under development. Advances in laboratory methods have improved the ability to measure chemicals and to generate biomonitoring data. The problems lie in the interpretation of the data, particularly data on environmental chemicals, which is still controversial and requires further study.

For more information about the biomonitoring studies currently underway at Health Canada, see **http://www.chemicalsubstanceschimiques.gc.ca/plan/surveil/bio-initiatives-enquetes-eng.php**

For more information about the Canadian Health Measures Survey, see **http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/chms-ecms/overview-vue-eng.php**

Challenges Ahead

Unravelling the effects of human exposure to toxic substances poses a great challenge. Given the many known factors and the strong probability of many as yet unknown factors (particularly in the case of chronic, low-dose exposures), it is extremely difficult to draw conclusive evidence. Technology to assess the impacts of multiple exposures to multiple substances is still under development. Data on human exposure and the prevalence of many effects are limited.

Epigenetics is the study of heritable changes in gene expression that are not caused by changes in the underlying DNA sequence (i.e., when non-genetic factors are the cause of genes' behaviour). Epigenetic evidence has brought a new understanding of the link between non-genetic processes and human health effects, and could play a major role in clarifying this relationship.

The potential impact of chronic exposure to the many new substances available today is still to be determined. Many feel that future research should further prioritize the effects of toxic substances on children. Children's systems are not fully developed. Proportionately, they eat, drink and breathe more than adults and are therefore at greater risk of exposure. Risk assessments should pay special attention to childhood exposures. To improve our understanding of developmental issues affecting children, a combination of epidemiological and clinical research, aided by improved surveillance of effects, is required.

Summary

In this chapter, we looked at some of the major human health effects that have been associated with exposure to toxic substances. As noted, we have not provided an exhaustive list. For a more in-depth understanding of the health effects covered in this chapter, refer to the Selected References and Useful Websites section of this primer.

In the next chapter, we turn our focus to the relationship between toxic substances and the environment. As humans, we are inextricably connected to our environment; therefore, its health is of primary concern.

Chapter Three

WHAT ARE THE IMPACTS ON THE ENVIRONMENT?

Big Great Lakes trout the most toxic, report says – CTV News, Wednesday, July 13, 2011

This chapter begins with a discussion of some of the general effects of toxic substances on ecosystems and wildlife, and then focuses on these impacts in aquatic and terrestrial ecosystems.

We now have a better understanding of how toxic substances affect human health, but how is the environment affected? The overall health of our environment depends on the health of the ecosystems on which plants, animals and humans rely. Aquatic and terrestrial ecosystems support a large variety of plant life and organisms. They can be threatened by factors such as habitat destruction, invasive species, climate change and toxic substances.

When a toxic substance enters an ecosystem, it can have a direct impact on individuals, populations and communities. An organism's ability to develop, reproduce and survive can be directly affected by acute exposures to high concentrations of a toxic substance or chronic exposures to lower concentrations. Toxic substances can also have indirect effects, as is the case when a predator species consumes contaminated prey.

Some toxic substances can enter a food web within an ecosystem and undergo various transformations during their passage. As we noted in Chapter One, bioaccumulation occurs when the uptake of an environmental substance by an organism is faster than its elimination. Toxic substances can become more concentrated (biomagnify) as they move up the food chain, sometimes reaching harmful levels in top predator species (e.g., bears, humans). While nutrients that are consumed can be converted into proteins or excreted as waste, some toxic compounds accumulate in the fatty tissue or organs.

The Polar Regions and Toxic Substances

Over the past several decades, significant levels of toxic substances from distant industrial and agricultural sources have been found in the wildlife and people of the polar regions. Some contaminants (e.g., mercury) come from as far away as Southeast Asia. Local contributions to contamination, in comparison, are relatively small and come from mines and radar stations. Toxic substances have been found in air, surface seawater, sediment, fish, marine animals, seabirds, and terrestrial plants and animals. Some of the contaminants are no longer used in Canada but are still used in other countries, so global co-operation with regards to reduction is vital.

Some toxic substances travel long distances along water and air currents and concentrate in the polar regions. Flame retardants, including PBDEs, that were originally used in electronic equipment have been found in penguins' eggs and krill in Antarctica. Recent data from the Arctic show the effects of chemical exposure (reduced immune response and reproduction) on the wildlife, including birds, seals and polar bears.

The people inhabiting the Arctic may also be affected. Studies of infant development have linked deficits in immune function, increases in childhood respiratory infections and changes in birth weight to prenatal exposure to persistent, bioaccumulative and inherently toxic substances.

The impacts of toxic substances on ecosystems are difficult to measure, largely because they involve various time frames. Impacts on individuals may appear in hours or days, but it can take years or even decades for effects on populations, communities and ecosystems to become apparent. Individuals often act as indicators of potential larger-scale impacts. Conversely, the effects of toxic substances on an ecosystem can be a clear indicator of potential impacts for human health.

Protection against the effects of toxic substances on ecosystems focuses on populations (e.g., a single species) and communities (e.g., numerous species) rather than individual plants or organisms. Protection involves maintaining the delicate balance within an ecosystem.

Toxic Substances and Ecosystems

Toxic substances can be transported from the soil into nearby lakes and rivers, evaporate from the water into warm air, be carried by wind and eventually be redeposited on land or water as temperatures cool, at which point the cycle begins again. This process is sometimes referred to as the “grasshopper effect” because the repetitions of the cycle mimic a hopping movement.

The exposure of living things to toxic substances is determined by the fate and distribution of these substances once they enter the ecosystem. For example, when a substance is emitted into a lake, it will distribute itself throughout the water column (a conceptual column of water from the surface to the bottom sediments) or form a slick on the water’s surface. In the water column, it can either remain dissolved or bind to the particles suspended in the water. In sediment, the substance may bind to the sediment particles or diffuse into the spaces between these particles.

Not all toxic substances will be available for uptake once they enter the environment. Some will attach strongly to soil and sediment particles, and become effectively unavailable for uptake by organisms. Others may be available initially, but rapidly transform or degrade into other substances. A transformed substance can be more or less toxic than its original form and more or less available for uptake by the surrounding environment. When mercury enters an aquatic environment, the bacteria in sediment can transform it into methylmercury, which is more available for uptake by organisms. Methylmercury binds tightly to the proteins of fish tissue and can bioaccumulate, reaching a level many times greater than that of the surrounding water.

The survival of individuals, populations and species is dependent on ecological relationships, such as predator-prey, competition for the same food source, and mutualism (whereby two species benefit from each other). Of equal importance for survival is the physical environment of an ecosystem, including its water quality and soil structure. The interrelated nature of ecosystems makes them sensitive to change, and they can be harmed by exposure to high concentrations of toxic substances.

Indications that an ecosystem has been affected by toxic substances include

- loss of species (e.g., some bird populations in the Great Lakes)
- accelerated proliferation of organisms (e.g., algal blooms as a result of excess phosphorus and nitrogen compounds in water)
- increased incidence of growths and deformities in plants and animals (e.g., tumours found in fish in the Great Lakes)

It is important to note that not all toxic substances cause these effects and that toxic substances are not the only factor contributing to these effects. A major cause of species loss is habitat destruction. Also, while toxic substances have been detected in the environment and in organisms, their long-term impact has yet to be determined.

Effects of Toxic Substances on Wildlife

Toxic substances have been linked to a myriad of harmful effects on all living things – micro-organisms, plants, invertebrates and vertebrates. The exposure of organisms to toxic substances in aquatic systems occurs from water (e.g., via the gills), the food web or sediment. In contrast, land-dwelling organisms may come into contact with contaminants through exposure to water, air, land or the food web. The impacts on species can include changes in hormone levels and in reproductive, foraging and feeding behaviours.

Substances may cause acute or chronic toxicity in wildlife, just as they do in humans. Acute toxicity effects typically range from skin irritation to death, while the effects of chronic toxicity include decreased reproductive success, impaired growth and a decreased survival rate. Some of the chronic effects that have been widely observed in wildlife include developmental deformities, like cross-bill syndrome in the cormorant, shell thinning in bird eggs and tumours in fish. Many of these effects have been found in the Great Lakes region, where PCBs and other substances have also inhibited the reproductive abilities of certain fish and wildlife species. The bald eagle population has recovered significantly from its decline in the 1960s, but the reproduction of the shoreline population is much less than that of the inland population, a finding that has been attributed to the greater contaminant levels in the diet of the former due to biomagnification.

In addition to having direct impacts on the health of different species, exposure to toxic substances can also reduce populations by causing death, lowering reproductive rates, or weakening members of a species so that they are increasingly vulnerable to predation, disease or parasites. Populations have been shown to decline over time through chronic exposure to toxic substances and to rebound if they develop a resistance or the substance is regulated. The number of herring gulls in the Great Lakes Basin has rebounded significantly since the 1970s as a result of legislation restricting the use of persistent toxic substances. Toxic substances may also indirectly increase a population by reducing the number of predators, leading to greater survival of their prey.

Some toxic substances have been shown to interfere with the physiological functioning of wildlife in both aquatic and terrestrial ecosystems. Egg yolk protein is normally produced only by breeding females; however, male snapping turtles and herring gulls now produce this protein as a result of endocrine disruption. Immunosuppression has also been observed, which may lead to increased susceptibility to infectious diseases and reduced ability to grow, compete for food and withstand changes in temperature.

INDICATOR SPECIES

Early concerns for wildlife stemmed from reproductive and developmental effects first observed in fish-eating birds in the Great Lakes Basin and other areas in the 1960s. Many areas in the Great Lakes are now under fish consumption advisories for one or more toxic substances, including mercury, PCBs and dioxins.

The impacts of toxic substances on wildlife, including fish, birds and some mammals, can be used as early warning signs of effects on ecosystems and human health. Known as indicator species, these types of wildlife are specific to a certain region and are usually chosen because they are near the top of a food chain and extremely sensitive to pollution or human interference. Any change in the species' health or numbers can indicate the presence of a toxic substance.

The Herring Gull – An Example of an Indicator Species

The herring gull is an excellent indicator species for environmental contamination in the Great Lakes for several reasons:

- The biology of the herring gull is well understood, as are many of the effects of environmental contamination on its physiology.
- Herring gulls are often permanent residents of one lake, rarely moving long distances.
- The herring gull is a top predator within the aquatic food web of the Great Lakes. Toxic substances that are difficult to measure in water or smaller organisms are easily measured in the eggs of herring gulls, where they have biomagnified to higher levels.

The herring gull cannot, however, be used to identify exposure to all toxic substances. It is not, for example, as sensitive to organochlorine compounds (used in some pesticides) as birds such as the bald eagle or cormorant. Furthermore, its large feeding area makes it a poor indicator of point-source contamination. Whether or not it will continue to act as a useful indicator species is open to question: its diet has changed significantly to include food from landfill sites, which could ultimately change its place in the Great Lakes food web.

The Great Lakes and Toxic Substances

The Great Lakes Basin has been a focus of concern in recent decades because it acts as a repository for pollutants, including some toxic substances, from direct and indirect sources. The Great Lakes are particularly vulnerable to the grasshopper effect due to colder water temperatures and large surface areas for airborne redeposition. The lakes played a critical part in North America's industrial revolution and remain surrounded by a concentration of industry and people. The water in the lakes replenishes slowly, at a rate of less than 1 per cent per year, so persistent chemicals are not readily flushed from the system. The Great Lakes, as aquatic ecosystems, allow for many links within the food web and the potential for biomagnification of toxic substances.

It was in studies of the Great Lakes that many scientists first observed the effects that toxic substances were having on the environment. Targeted actions to control many of the sources of toxic substances have resulted in a significant improvement to water quality; however, the presence of emerging substances in the lakes has created new areas of concern. Many of these emerging, potentially toxic substances come from consumer products rather than industrial sources, so the focus of preventive measures must shift in order to address them.

BACKGROUND

When whole populations of cormorants, herons and gulls living on the lakes began to disappear in the 1960s and 70s, scientists realized that the threat of toxic chemical pollution had become a reality. Toxic substances were discovered in wildlife during routine monitoring. Some bird populations disappeared, others had difficulty hatching their eggs and still others could not reproduce at all. Fish showed signs of contamination as well, including tumours and reproductive effects.

Water pollution controls enforced by Canada and the United States in the 1970s reduced the dumping of suspended solids and oxygen-depleting materials. PCBs and DDT were banned, so that their levels in the environment decreased. Despite these measures, studies performed in the mid-1980s still showed the presence of toxic substances in the Great Lakes. Many had bound themselves to particles in the water and moved to the sediment; while initial concentrations in the water and fish were reduced, these toxic substances were eventually released back into the water from the sediment.

EFFECTS ON THE ENVIRONMENT AND HUMAN HEALTH

Toxic substances not only affected the water quality in the Great Lakes but also had an impact on the region's wildlife and human population. The extent of this impact is still relatively unknown. Studies of Great Lakes indicator species (e.g., herring gulls, bald eagles, snapping turtles) reveal endocrine disorders, metabolic diseases, altered immune function, reproductive impairment, developmental toxicity and cancer. In the Great Lakes Basin, fish-eating birds are at the top of the food web. Populations of several species, including herring gulls, cormorants and black-crowned night herons, were critically depleted in the 1960s and 70s. Bird species were particularly affected by dioxin, which caused thinning egg shells and birth defects, such as extra limbs and crossed beaks, in chicks. By the late 1970s, decreases in the levels of toxic substances allowed many species to regain their vitality. Emerging substances are now being detected in wildlife in the basin. Data show, for example, that between 2000 and 2005, the presence of flame retardants in herring gull eggs increased by approximately 25 per cent.

Potential pathways of human exposure to pollutants in the Great Lakes include inhalation of air; ingestion of water, contaminated food or soil; and dermal contact with water or airborne particulates. Testing has revealed higher levels of mercury in the blood and body tissues of people who eat large quantities of fish from the Great Lakes. Among those who rely on fish as a staple are new Canadians, Aboriginal peoples and inhabitants of rural communities. Mercury levels in the Great Lakes are high enough to cause developmental defects and neurological problems in the children of those who rely on fish in their diet.

LEGISLATION AND SUCCESSES

The governments of Canada and the US signed the first Great Lakes Water Quality Agreement (GLWQA) in 1972. A revised agreement, signed in 1978, furthered initiatives to improve water quality, and to reduce, where possible, and manage the presence of toxic substances in the Great Lakes. In a 1987 amendment to the GLWQA, the two countries agreed to restore 43 areas of concern (AOCs), which suffered from severe degradation. AOCs were identified based on human activities (eating fish, drinking water and swimming) and ecological impacts (loss of wildlife habitats, and bird and animal deformities).

In 1997, Environment Canada and the US Environmental Protection Agency signed the Great Lakes Binational Toxics Strategy (GLBTS) (see Chapter Five). It set 17 goals in order to reduce the use and presence of 12 high-priority substances, and implement pollution prevention measures that would reduce levels of an additional list of toxic substances. Of the 17 goals established in 1997, 13 have been achieved and significant progress has been made on the remaining four. One of Environment Canada's goals was to achieve a 90 per cent reduction from the 1988 baseline for mercury releases in Ontario. They were reduced by slightly more than 90 per cent (by 12,600 kilograms) between 1988 and 2006. The greatest reduction in releases has been from the electric power generation sector (i.e., the burning of coal).

The Government of Canada and the Ontario provincial government ratified the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA). The intent of the COA is to restore and protect the Great Lakes Basin, which helps Canada meet its GLWQA commitments. The provincial and federal governments also work with partners at the local level in the Great Lakes community to achieve these goals. The COA was originally signed in 1971 and has been renewed several times since, most recently in 2007.

MOVING FORWARD – SUBSTANCES OF EMERGING CONCERN

While the GLWQA and other regulations have helped reduce many toxic substances in the Great Lakes, including mercury, lead and PCBs, emerging contaminants continue to be identified, their risks assessed and appropriate actions taken. Some emerging chemicals of concern include bisphenol A (BPA), phthalates, nonylphenols, and polybrominated diphenyl ethers (PBDEs) and other flame retardants. Many of these chemicals come from non-point sources: they have been found in surface water, groundwater, drinking water, aquatic species, sewage biosolids, soil and sediments in the Great Lakes Basin. In Lake Superior, the level of PBDEs in some fish species has doubled every three to four years during the period between 1980 and 2000. A Government of Canada screening assessment concluded that a number of PBDEs are entering the environment at levels that could have harmful effects on the ecosystem. In response, the government established the *Polybrominated Diphenyl Ethers (PBDE) Regulations*, which came into force in June 2008. These regulations prohibit the manufacture of all PBDEs in Canada and restrict the import, use and sale of those found in the commercial mixtures of greatest concern (Penta- and OctaBDE).

Figure 3-1: Great Lakes: Areas of Concern

Adapted from Environment Canada
Available at http://www.ec.gc.ca/raps-pas/default.asp?lang=EnGn=96A7D1F1-1

Aquatic Ecosystems

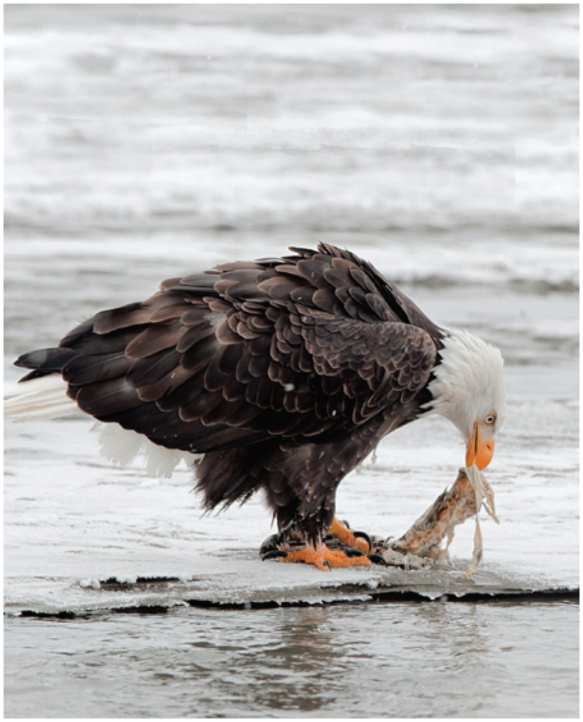
Aquatic ecosystems such as lakes, rivers, floodplains and wetlands are made up of organisms that are dependent on each other and their water environment for survival. They sustain large and small life forms, including bacteria, plankton, bulrushes, worms, snails, fish, amphibians, reptiles and birds. Aquatic ecosystems are also vital to humans, who use and consume water from these sources. The habitat conditions unique to each ecosystem directly affect species distribution and organization. Fast-flowing rivers, for example, attract species that can adapt to such conditions and would not thrive in the still water ecosystem of a lake.

Toxic substances can affect organisms that live in the water column (aquatic plants, invertebrates and predatory fish) and in the sediment (worms and mollusks). They tend to accumulate in sediment because they can bind to the sediment particles. The entry of a toxic substance into the food web often occurs when sediment-dwelling organisms feed on freshly deposited organic material and suspended solids at the bottom of a body of water or burrow into and ingest sediment below. The health of these sediment-dwelling organisms is key to the survival of the ecosystem, as they play an important role in the recycling of loose material found in water. Fish exposed to toxic substances early in their development have impaired hatching success, survival and growth. Studies in the Great Lakes Basin have found an increased rate of lip and skin growths, and, in some cases, tumours in the liver and intestines in fish that were captured in polluted areas.

Water contamination can cause a decline in fish populations, thus affecting the fishing industry. Those fish that do survive may contain unsafe levels of toxic substances, such as mercury. In the late 1980s, concerns about the impacts of pulp and paper effluents on the fish population in Canada led to the drafting of the federal *Pulp and Paper Effluent Regulations*, which require the establishment of monitoring programs to track the effectiveness of measures taken to reduce adverse effects on fish.

Terrestrial Ecosystems

“Terrestrial ecosystem” refers to the interrelations of organisms found on land. Toxic substances have been associated with potentially harmful effects on soil organisms, plants and wildlife. Soil organisms are of particular concern because they enable the breakdown of matter, the formation of soil structure and the cycling of nutrients. The effects of toxic substances in a terrestrial ecosystem range from reduced growth rates in soil invertebrates to the inhibition of soil bacteria, fungi and microbes. In plants, toxic substances such as cadmium are taken from the soil and redistributed in roots, shoots and leaves, impairing growth. Crops exposed to cadmium show decreased yields.



Exposure of predatory birds and large mammals (including humans) typically occurs as a result of diet. Perfluorooctane sulfonate (PFOS), which bioaccumulates in fish, can have a harmful impact on mammals. While fish are able to eliminate some PFOS through their gills, predators without gills, higher up the food chain – birds, mink and foxes – have been found with high concentrations in their liver and blood. Exposure to PFOS can result in growth inhibition, changes in species diversity and, in some cases, mortality.

The effects of toxic substances on terrestrial organisms are less known than those affecting their aquatic counterparts. Terrestrial animals often travel significant distances to forage, defend their territories or seek out more amenable living conditions, making the location and means of their exposure (contaminated air, water, soil or food) difficult to track. Furthermore, while a body of water maintains a relatively steady temperature because of its high heat capacity, terrestrial environments may undergo sudden changes in temperature, which may be responsible for health effects that could be misattributed to toxic substances.

In many cases, mechanisms exist that allow us to help minimize the detrimental impacts caused by toxic substances or even to restore ecosystem health. Environmental legislation has introduced controls to safeguard human health and the environment from exposure and the risks associated with the use and release of these substances at unsafe levels. Technological advances have also helped to improve the quality of emissions and effluent released to the environment. Monitoring of substance emissions and the tracking of existing problems have also improved. Both federal and provincial governments in Canada monitor everything from climate and weather conditions to wildlife populations and water levels. Governments also analyze samples of air, water, soil and tissue for pollutants.

Polybrominated Diphenyl Ethers (PBDEs) – Substances Considered Toxic According to the Environmental Criteria of CEPA 1999

PBDEs are commonly used as flame retardants and heat stabilizers in a variety of products. They are part of the plastics used for building materials, television and computer casings, carpets, foam and fabric for furniture. PBDEs have been found in indoor and outdoor air, house and office dust, rivers, lakes, sediment, wildlife and food. They have also been found in human breast milk. Animal studies and limited human data show evidence of thyroid hormone disruption and additional endocrine system effects. Animal studies have also shown that PBDEs are toxic to the developing nervous system and act as reproductive toxicants. They are suspected carcinogens and may have additive effects with PCBs and dioxins.

While overall concentrations of PBDEs are low, the current levels – found in air, water and land – may still threaten some wildlife and invertebrates. PBDEs tend to bind to particulate matter, soil and sediment, and can be transported long distances in the form of particles. Studies indicate that PBDE levels in Canadian biota have increased dramatically over the last two decades. The highest levels in biota are associated with industrial regions; however, there is increasing evidence of PBDEs in Arctic biota, including the Arctic ringed seal.

Challenges Ahead

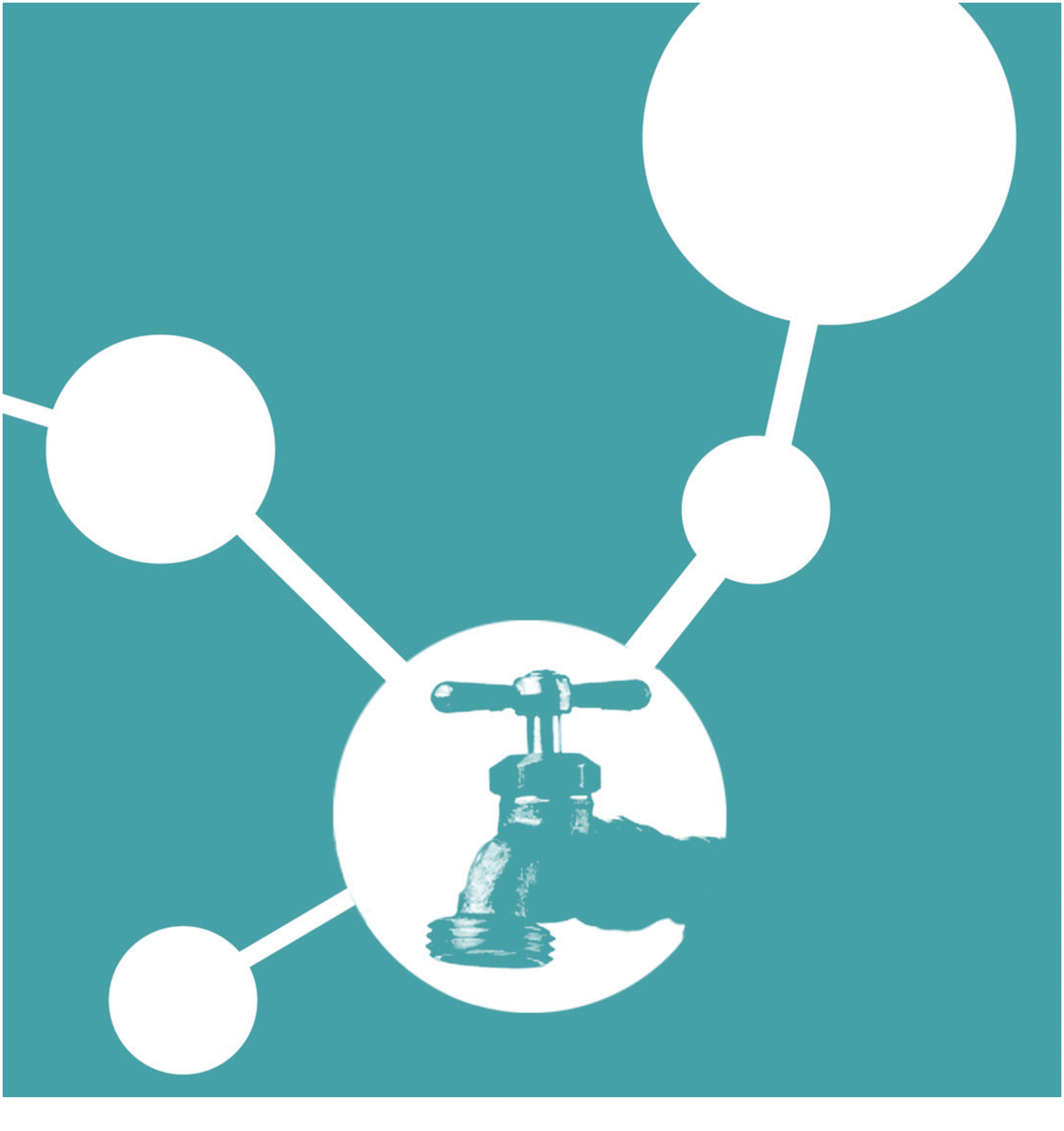
We can minimize the detrimental impact of toxic substances and, in some cases, restore ecosystem health. Environmental legislation, technological advances, and monitoring have made significant progress in addressing these issues, but we cannot relax our vigilance because there will continue to be new challenges.

Habitat loss and destruction have caused some species to search for food sources outside their traditional food chain, resulting in a shift in their position within the food web. In the future, this will have a direct impact on the suitability of important traditional indicator species, which may no longer provide an early warning system. We may come to recognize new and previously unseen environmental issues. Persistent substances, even those that may have been regulated for years, will continue to be of concern, as they do not break down easily.

As noted in this chapter, the health of our ecosystems also has a direct effect on human well-being because contamination can have implications for many industries. For example, the future of the fishing industry hinges on ensuring that fish populations do not decline and that the fish themselves do not contain unsafe levels of toxic substances. Managing toxic substances and ensuring healthy ecosystems is, therefore, of concern not only for the future of the environment but also for the continued success of the economy.

Summary

The environment often acts as an early indicator of the potential effects of toxic substances. Toxic substances have been discovered in geographic areas as far away as the polar regions, evidence that these substances travel long distances and do not necessarily break down quickly. Chapters Two and Three have concentrated on the potential effects of toxic substances on human health and the environment. But how do these substances find themselves in the environment in the first place? In the next chapter, we look at some of the sources of toxic substances.



Chapter Four
WHERE ARE TOXIC SUBSTANCES FOUND?

Small amounts of arsenic found in chicken feed: FDA – Toronto Star, June 8, 2011

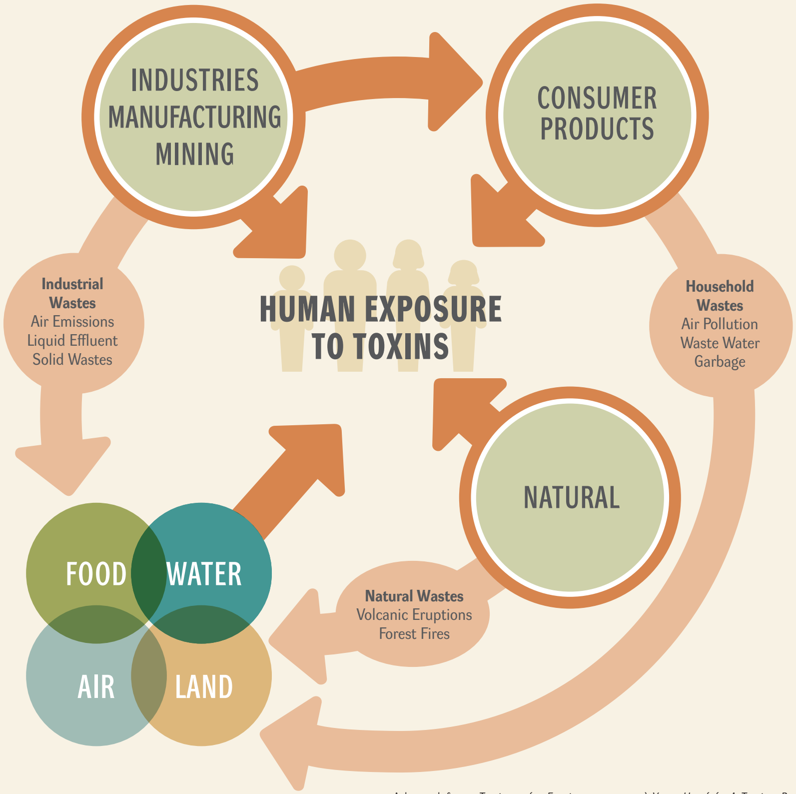
Exposure to toxic substances can be measured as contaminant levels in blood and other tissues, and in air, water, food, soil or dust. As noted in Chapter Two, exposure to a toxic substance does not necessarily result in a negative health effect. Each toxic substance has its own properties, exposure routes and resulting implications. This chapter examines, in more detail, some of the ways in which exposure to toxic substances may occur. The potential for exposure during the life cycle of a toxic substance is described, from releases (natural or resulting from human activities) to use in industry and consumer products. This is followed by a discussion of exposures related to diet, indoor and outdoor air quality, dust, drinking water and working conditions.

The Life Cycle of Toxic Substances

Toxic substances can show up in any number of places, including chicken feed and children's jewellery. But how did they get there? As we have seen, some toxic substances travel easily throughout the natural environment. While some are released through natural combustion, most are released through human activities, such as transportation (gasoline, diesel and jet exhaust), heating (gas, oil and wood), thermal generation of electricity (coal), mining, industrial processes, incineration of waste and disposal of products that contain toxic substances. Some toxic substances such as mercury have the potential to cycle almost indefinitely once they have entered the environment.

As Figure 4-1 shows, humans can be exposed to toxic substances through contact with industrial sources, consumer products, and contaminated air, water and food. The relative magnitude of releases from these sources is specific to the substance and its geographic region. Some toxic substances may break down or degrade over time, reducing the amount found in the environment.

Figure 4-1: Life Cycles of Toxic Substances



Adapted from *Toxics, the Environment and Your Health: A Toxics Reduction Strategy for Ontario*, http://www.ontla.on.ca/library/repository/mon/23004/291308.pdf
©Queen's Printer for Ontario, 2011, p. 3

In 2009, over half (58 per cent) of the pollutants reported to the federal NPRI were emissions of criteria air contaminants (CACs), the main pollutants in smog, acid rain and poor air quality. Some of these CACs (e.g., VOCs, sulphur dioxide and particulate matter) are considered toxic substances according to CEPA 1999. The largest reported releases of CACs were from oil and gas extraction, primary metal smelting, and electricity generation, transmission and distribution. Releases to air of substances other than CACs accounted for only 3.5 per cent of total pollutant releases in that year. While these findings give us an indication of which substances make up a large portion of emissions, they should be qualified. It is difficult to make comparisons based on the measurement of pollutants reported to the NPRI because the units and the type of measurements vary, depending on the reporter's focus. For example, dioxins and furans are tracked at a much lower magnitude than particulate matter. Furthermore, emissions below the reporting threshold are not captured in the data. Figure 4-2 illustrates the pollutant contributions to air, water and land through releases and recycling and disposal activities for 2009.

Where Do Toxic Substances in the Environment Come from?

Toxic substances are released into the environment in five ways:

- intentionally
- incidentally (or unintentionally)
- through creation of a by-product that is a toxic substance
- naturally
- accidentally

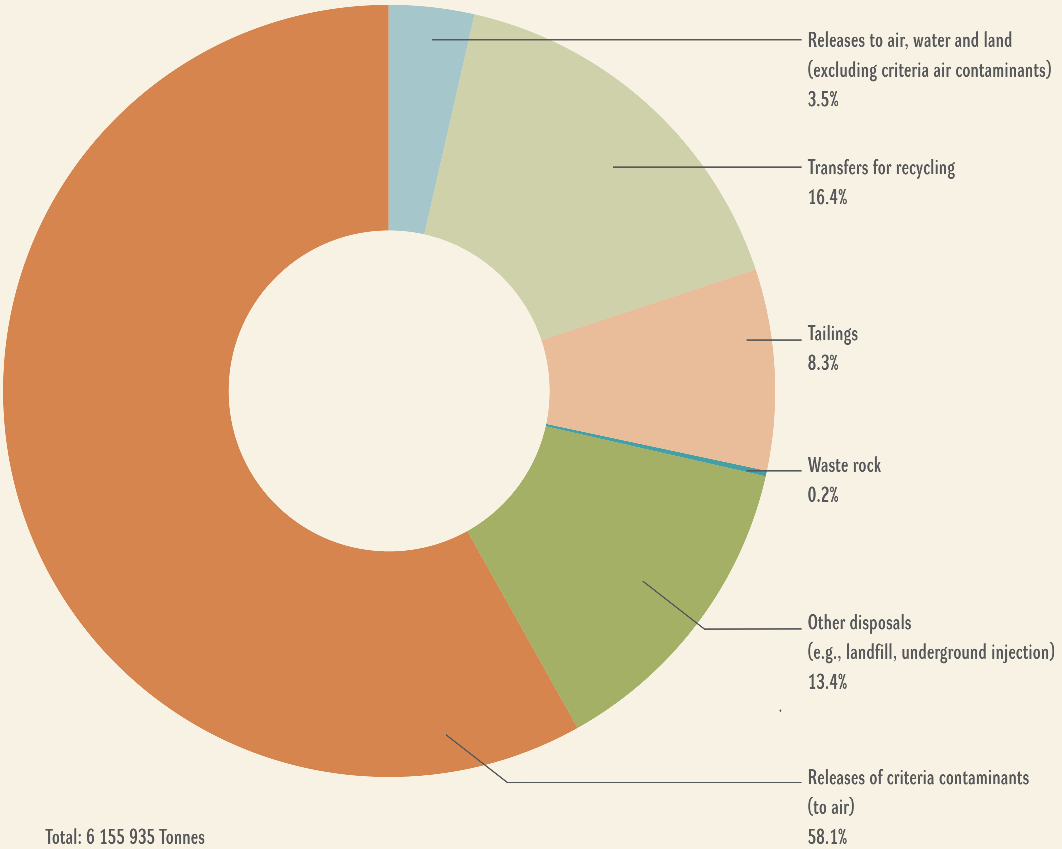
INTENTIONAL USE OF TOXIC SUBSTANCES

Toxic substances may be released into the environment as a result of their deliberate use. Releases under this heading fall under two general categories. The first occurs during the manufacture, breakage or disposal of a product that intentionally contains a toxic substance. The second enters the environment when a toxic substance is used in an industrial process, such as a solvent in a chemical factory. Not all intentional releases pose a risk to humans or the environment, and even where there are some risks, the social and economic benefits of the product or process may outweigh them.

Mercury is a toxic substance that is used intentionally both during industrial processes and in products. The "mercury cell" process was used in some chlor-alkali plants (where chlorine, sodium hydroxide, sodium bicarbonate and potassium hydroxide are produced). It can result in the release of low levels of mercury from the facility into the air, and site contamination of water and land. In Canada, the *Chlor-Alkali Mercury Release Regulations* limit the release of mercury from mercury cell chlor-alkali plants. Today, there are no chlor-alkali plants in Canada using the mercury cell process: companies have transitioned to membrane or diaphragm cell processes that do not require the use of mercury. Mercury continues to be used intentionally in reduced quantities, however, in products such as compact fluorescent light bulbs (CFLs), electrical switches, batteries and dental amalgam.

A toxic substance may also be used intentionally as a raw material. For example, lead is used deliberately in lead-acid batteries and as a stabilizer in some plastics and rubbers.

Figure 4-2: Total Releases, Disposals and Recycling (Off-site) Reported to the National Pollutant Release Inventory for 2009



The criteria air contaminants (CACs) in this pie chart refer to the substances listed under Part 4 of the National Pollutant Release Inventory (NPRI). Ammonia can also be considered a CAC, but it is reported under Part 1 of the NPRI list. Release data for ammonia are reflected under the category "releases to air, water and land."

Adapted from Environment Canada's National Pollutant Release Inventory (NPRI), 2009
Available at www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=7535CAAC-1

Cadmium – An Example of a Toxic Substance with Multi-source Releases

In 1994, Canada determined that inorganic cadmium is toxic according to CEPA 1999. Cadmium enters the environment through metal production (base metal smelting, refining), stationary fuel combustion (power generation, heating), transportation and solid waste disposal (incineration of municipal waste materials). It is absorbed through inhalation (air emissions from industry, cigarette smoke) and ingestion (from food and water, and, in the case of young children, from ingestion of soil/dust and certain coatings). It is toxic to the kidneys and has been associated with cancer.

A naturally occurring element and a metallic component of the Earth's crust, cadmium was discovered in 1817 in Germany as a by-product of zinc refining. It is found throughout the Arctic, but its impact in that region has not been determined. Cadmium metal has a low melting temperature and high thermal and electrical conductivity, and is highly resistant to corrosion. The most notable application of cadmium is the nickel-cadmium battery, which has proliferated over the last few decades.

In 1912, a local rice crop in a Japanese community became contaminated with cadmium, resulting in chronic poisoning, which became known as itai-itai. Forty per cent of the exposures were from eating contaminated rice. Cadmium concentrations in the Canadian diet have remained constant since 1992.

Increasingly, the global community is taking measures to manage the release of cadmium from human activities. In 2005, the UNEP Governing Council initiated a review of the scientific information on cadmium to act as the basis of future discussions on global actions in response to its effects. In 2009, it declared "further action is needed to address the challenges posed by lead and cadmium" and supported "efforts by Governments and others to reduce risks to human health and the environment of lead and cadmium throughout the whole life cycle of those substances and to take action to promote the use of lead and cadmium-free alternatives, where appropriate" (see http://www.unep.org/gc/gc24/docs/GC24_decisions.pdf).

INCIDENTAL RELEASES

Incidental releases occur when toxic substances present in a natural substance (e.g., the Earth's crust) are released into the environment as a result of human activity (e.g., the burning of coal releases mercury into the environment). These emissions occur as a result of an industrial activity that does not involve the direct or deliberate use of a toxic substance. Many metallic elements that are found naturally in rock, coal, processing metals such as copper and zinc, and oil release toxic substances when they are processed or burned. In Canada, incidental releases are subject to regulatory controls.

Arsenic – An Example of a Natural Release

Arsenic is a naturally occurring element in our environment. The main source of arsenic exposure for humans is food, primarily fish and shellfish. It can be released into the air through volcanic eruption, the weathering of arsenic-containing minerals and ores, and as a result of some industrial processes. Chromated copper arsenate (CCA) is used in the production of pressure-treated wood to protect wood from damage by insects, mould, sun and water. Chromium, copper and arsenic can leach out of CCA-treated wood and build up in the surrounding soil and on the surface of the wood. While the risk of illness from exposure to arsenic leaching from pressure-treated wood is low, a voluntary phase-out of CCA-treated wood for residential use began in Canada in January 2004. Though industrial use continues, CCA-treated wood is now banned for non-industrial uses in Canada.

While small amounts of arsenic may not be harmful to human health in the short term, unnecessary exposure should be avoided as it is a known carcinogen. In humans, chronic exposure to arsenic can cause cancer, toxic effects in the nervous and cardiovascular systems, and skin lesions. In lab testing, arsenic has caused immune system toxicity in animals. According to the World Health Organization, every year, thousands of people in Bangladesh, India, Cambodia, Vietnam and Myanmar die of skin cancer or other health issues believed to be caused by chronic exposure to arsenic through contaminated groundwater. Arsenic is present in the groundwater in some areas of Canada, usually those close to a natural geological source or a contamination site. High levels have been found in Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia and British Columbia.

Cadmium is found naturally in the Earth's crust, often in combination with zinc. It may be incidentally released through activities such as the manufacture and smelting of zinc from its ore. The toxic substances acetaldehyde, toluene and benzene are released during domestic wood burning.

CREATION OF A BY-PRODUCT

Toxic substances can also be created unintentionally and released into the environment as by-products of an industrial process. This class of toxic substances includes chlorinated dioxins and furans that form as by-products of any low-temperature combustion process where chloride or chlorine is also present. The "open barrel" burning of household wastes is currently a major source of dioxin and furan release into the air in rural areas.

Pulp and paper mills use defoamer additives that often contain dibenzofurans and dibenzo-para-dioxins to help manage the properties of process water. During the chlorine bleaching process, these chemicals react with chlorine to form the by-products polychlorinated dioxin and furan, which were assessed as toxic substances under CEPA 1999 and have been regulated for some time.

NATURAL RELEASES

Toxic substances belonging to the natural environment can be released through natural processes. For example, a volcanic eruption can release toxic substances from the Earth's crust, including mercury, arsenic and cadmium. Other sources of naturally occurring toxic substances can be found in airborne soil particles, sea spray and biogenic material. Forest fires have also been shown to release a range of toxic substances, such as cadmium, mercury and dioxins (in fact, forest fires account for the majority of dioxins released into the environment). While dioxins are released as a product of combustion, other toxic substances absorbed by the roots of trees are released to the environment when the trees burn.

ACCIDENTAL RELEASES

Trucks, trains and large tankers are often responsible for transporting wastes containing toxic substances from industrial sites to treatment facilities. Toxic substances can be released into the environment as the result of spills, leaks and other accidents during transport. Oil spills, for example, can happen on land or on water when oil is mishandled, during railway or truck accidents, or when tankers or barges collide. Crude oil contains substances that pose potential short- and long-term risks to human health, including benzene and polycyclic aromatic hydrocarbons (PAHs).

Accidents such as fires or explosions at industrial sites can also release toxic substances, though industry and government measures are in place to prevent, or respond to, potential hazards. In the event of an accident, acute and chronic exposure can be high depending on the amount of the toxic substance released at the time and the effectiveness of the clean-up.

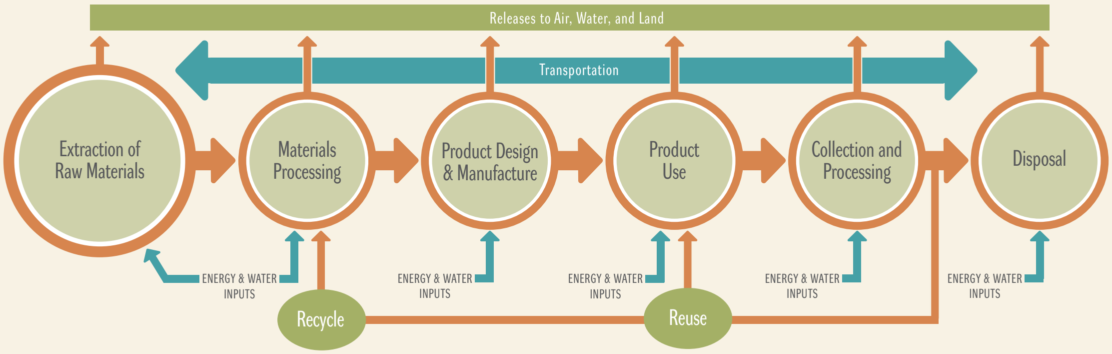
Polycyclic Aromatic Hydrocarbons (PAHs) – An Example of an Accidental Release

PAHs are released into the environment as a result of natural and human activities. Forest fires are responsible for most natural emissions of PAHs in Canada. Human activities such as wood heating and aluminum smelting also release PAHs. Aquatic and soil environments absorb PAHs through creosote-treated products, spills of petroleum products, metallurgical and coking plants, and deposition of atmospheric PAHs. Highly aromatic oils containing PAHs are added to tires during manufacturing to make the rubber polymer easier to manipulate and the tire tread soft. Every year, large quantities of small rubber particles containing PAHs wear off tires, dispersing PAHs along roads and ultimately into the environment. A more significant release of PAHs, however, may be through vehicle exhaust. PAHs have been linked to certain types of cancer, as well as cataracts, kidney and liver damage, and jaundice.

Manufacturing Processes

Figure 4-3 illustrates the general chemical flow of materials through the manufacturing process and indicates potential points of release for toxic substances. Some toxic substances are raw materials in consumer products. Vinyl chloride, a toxic substance according to the criteria of CEPA 1999, is used in the formation of polyvinyl chloride (PVC), a common plastic. Toxic substances may also be used during the shaping of a product to form, mould or assemble it. Adhesives or resins that contain formaldehyde, for example, can be used to press veneer. Also, finishing operations may involve the use of dyes containing heavy metals, trichloroethylene to clean the surface of fabricated metal products, or acetone to clean circuit boards used in electronics. Many toxic substances are emitted during the final steps of manufacturing processes: the cleaning of equipment and the disposal of wastes. Arsenic and lead, both found naturally in ore, are present in the dust released from mining sites.

Figure 4-3: The Chemical Flow of Materials



Adapted from "Chemical Management Services: A lifecycle approach to reducing chemical use and costs," presented by Jill Kauffman Johnson at US Environmental Protection Agency's "Materials Matter: A Lifecycle Approach to Materials Management" Workshop, March 23-25, 2010.

Some of the industries that use and release toxic substances include

CHEMICAL MANUFACTURING – This industry produces a wide range of chemicals: pesticides, paints, adhesives, cleaning compounds, synthetic dyes, pigments and petrochemicals. Toxic substances may be used as colourants, flame retardants (chlorinated paraffins), heat stabilizers (lead, cadmium) or plasticizers (phthalates).

PETROLEUM PRODUCTION – Refineries process crude oil into fuels, including gasoline, diesel and lubricating oils. The process of refining crude oil produces by-products such as benzene, toluene and sulphur dioxide.

COAL-FIRED ELECTRIC POWER GENERATION – Coal-fired power plants can emit mercury, dioxins and furans, nitrogen oxides and sulphur dioxide into the air.

PLASTICS AND RUBBER PRODUCTION – This industry manufactures plastic resins and natural and synthetic rubber, including tires, plastic bottles and plastic foam products. As is the case in chemical manufacturing, toxic substances may be used as flame retardants, heat stabilizers and plasticizers.

Management of manufacturing and mineral-processing facilities using prescribed substances are required to report to the Government of Canada under the federal NPRI and the Ontario Ministry of the Environment under the Ontario *Toxics Reduction Act* if they meet the criteria prescribed.

Toxic Substances in Consumer Products

It is often assumed that toxic substances enter the environment primarily as a result of industrial releases, but they can also be released from consumer products during use and disposal. Consumer products generally contain ingredients that need to be assessed to ensure that they do not pose potential risks to human health or the environment. For some products, the extent and effects of human exposure are well understood, but in other cases, our knowledge is limited. The government regulates the use of toxic substances in consumer products, and Health Canada maintains a publicly available list of products that have been recalled due to safety concerns, including the presence of toxic substances.

To view the list, see **http://cpsr-rspc.hc-sc.gc.ca/PR-RP/home-accueil-eng.jsp**

CONSUMER PRODUCTS CONTAINING TOXIC SUBSTANCES

Some consumer products that contain toxic substances may release them during regular use, even when used according to their safety directions. The production, import and use of the following substances is regulated:

- VOCs, which evaporate into the air at room temperature and are present in products such as glue, paint, air fresheners, new furniture or carpets, mothballs and many cleaning and personal care products. Canada's new VOC regulations aim to ensure that if any VOCs are present, they are kept at low levels.
- polybrominated diphenyl ethers (PBDEs), which are used as flame retardants and can be released from products such as plastics, electrical and electronic equipment, upholstered furniture, non-clothing textiles and foam products. The *Polybrominated Diphenyl Ethers Regulations* prohibit the use, sale and import of a number of PBDEs and the manufacture of PBDEs in Canada.
- perfluorinated compounds (PFCs), which are persistent, bioaccumulative and often toxic to humans and wildlife. PFCs are used to make textiles, including clothing, stain- and water-repellent. Human exposure to PFCs can occur during manufacture, use and disposal. Two primary classes of PFCs are used in textile manufacturing: perfluorooctane sulphonates (PFOS) and fluorotelomers. Perfluorooctane sulphonates are considered toxic under CEPA 1999 but continue to be used in other countries, while four fluorotelomers were recently added to the CEPA 1999 List of Toxic Substances.
- benzene, cadmium, arsenic and toluene, which are just a few of the toxic substances found in cigarettes. Smoking and second-hand smoke are direct sources of exposure to many toxic substances.
- phthalates, which are a diverse group of chemicals, mainly used to soften plastic, that can be released over time. Some phthalates are found in consumer products such as children's products, medical equipment, flooring, packaging, paints and lubricants. While not all phthalates are of concern, Canada has taken steps to address those that are potentially harmful with the *Phthalates Regulations* administered under the authority of the *Canada Consumer Product Safety Act*.
- bisphenol A (BPA), which is a synthetic chemical used primarily in the production of polycarbonate plastic products, including CDs, DVDs, electrical equipment, automobiles, sports safety equipment, hard plastic water bottles, and food and drink cans. One pathway of human exposure is through food that has been packaged with plastic containing BPA. In 2010, Canada became the first country in the world to regulate BPA, adding it to the CEPA 1999 List of Toxic Substances.

The misuse or damage of a consumer product may also result in the release of a toxic substance. While in use, a compact fluorescent light bulb (CFL) containing mercury does not pose a health threat; however, if it breaks, a small amount of mercury will be released into the surrounding area.

THE IMPROPER DISPOSAL OF CONSUMER PRODUCTS

Toxic substances can also be released into the environment through improper disposal of a product. While many regions restrict the dumping of products such as batteries and electronics, these products still find their way into landfills. When waste is incinerated, toxic substances can be released as incidental emissions (these are not unintentional releases, because they are the result of the deliberate use of toxic substances).

Mercury can be released from landfills, in waste water, and as a result of the incineration of products such as fluorescent lamps, electrical switches, batteries and thermostats. Mercury in landfills can evaporate slowly into the air or enter the surrounding soil where it can contaminate groundwater. The disposal of mercury is a challenge because it cannot be destroyed, only contained.

Exposure to Toxic Substances in Our Daily Lives

Toxic Substances in Our Diet

One of the major pathways of exposure to toxic substances is through our diet. Some toxic substances, such as cadmium, are taken up by plants (often leafy vegetables), while others such as methylmercury bioaccumulate and, in some cases, biomagnify up the food chain. A number of toxic substances occur naturally in our food, such as 1,2 benzenediol, which is found in apples, potatoes and some refined olive oil. PAHs are naturally present in coffee, most likely due to the degradation of coffee compounds during the roasting process. Pesticide and fertilizer residues may also be found in food. Toxic substances can also be added intentionally as food preservatives, although when they remain within the food safety guidelines, the benefits are thought to outweigh the risk. Food packaging is a major source of exposure to BPA and some phthalates. For developing embryos and fetuses, exposure to toxic substances can occur through diet in the womb, and for babies, through breast milk. As discussed previously, the resulting effects of toxic substances, whether found naturally or added to our food, are related to a number of factors including toxicity, duration and timing of exposure.

Some plants absorb substances more easily than others. Leafy plants, for example, tend to take up more cadmium than root vegetables. Studies have shown that dietary intake and absorption of some substances in humans are strongly linked to the presence of other elements in the diet. “Bioavailability” refers to the degree to which a substance is absorbed. For example, when iron, zinc and calcium are present in the diet, cadmium absorption is not significant. A deficient level of these three elements in rice is believed to be the reason for increased absorption resulting in effects such as itai-itai disease.

In many regions of the world, the contamination of fish has resulted in advisories and consumption guides aimed at protecting human health. The Ontario *Guide to Eating Ontario Sport Fish*, updated annually, presents the results of analyses of lead, dioxin and PCB levels of samples from 1,860 locations throughout the province’s inland lakes and rivers, as well as the Canadian waters

Bisphenol A (BPA) – An Example of Exposure Related to Diet

Bisphenol A, or BPA [Phenol, 4,4′-(1-methylethylidene) bis- in the federal government's List of Toxic Substances], is a synthetic chemical used primarily in the production of polycarbonate plastic and epoxy resins. Polycarbonate plastic is extremely durable and used in digital media, electrical equipment, automobiles, sports safety equipment, hard plastic water bottles, and food and drink containers. Epoxy resins are used in electrical laminates for circuit boards, composites, paints, adhesives and protective coatings. Cured epoxy resins are used in the liners of metal cans.

Human exposure appears to be mainly through food packaging; however, Health Canada does not consider this source of exposure to pose a risk to the general population, including children.

BPA has been linked to reproductive and developmental toxicant issues in animals and is a suspected endocrine disruptor. Some studies have indicated that BPA may be of concern even at the low doses at which it is currently found in the environment. Statistics Canada released new data in August 2010 showing that BPA was present in roughly 91 per cent of the Canadian population, particularly in those aged 12 to 19. Although a definitive link to effects in humans has not been demonstrated, some jurisdictions have moved to take precautionary measures to protect sensitive populations from BPA. When it prohibited polycarbonate baby bottles containing BPA under the *Hazardous Products Act* in October 2010, Canada became the first jurisdiction in the world to declare BPA a toxic substance as a precautionary measure. This is the first step in the development of risk management strategies to deal with the human health and environmental risks of BPA.

of the Great Lakes. The guide provides specific advice for women of child-bearing age and children under 15 years of age due to their increased vulnerability to toxic substances. Some fish found in the supermarket may also contain PCBs or mercury, but not in levels that would cause immediate health effects. Chronic exposure from regular consumption of contaminated fish, however, can elevate concentrations in the body to levels of concern.

For more information on fish consumption, see the *Guide to Eating Ontario Sport Fish* or the following sites: **http://www.toronto.ca/health/fishandmercury/index.htm** and **http://www.peelregion.ca/health/eatfish**

THE DEVELOPING FETUS AND BABY

For the developing embryo and fetus, exposure to toxic substances occurs through the blood vessels of the placenta in the womb. A baby's diet often consists of breast milk (which many health organizations agree is the best food for an infant) or formula; both can contain toxic substances.

The Womb

The placenta carries oxygen, water, nutrients and other substances required for the development of the embryo and fetus. It acts as a semi-permeable membrane that blocks unwanted bacteria and is thus able to detoxify many foreign substances. Still, it cannot block all toxic substances that the mother may be exposed to, especially those that are small, light and easily dissolved in fatty tissue.

Breast Milk

Breast milk is recommended for a baby's development for at least six months after birth. It contains everything an infant needs, while contributing to brain and cognitive development. The first breast milk, colostrum, is full of proteins, vitamins, antibodies, growth-promoting substances and living immune cells. Colostrum and breast milk help an infant fight off disease by passing on temporary immunity from the mother.

Toxic substances can accumulate in the fatty tissue of humans, just as they do in other organisms. Some toxic substances, including flame retardants (PBDEs), PCBs and dioxins, have been found in trace amounts in breast milk; in the case of some substances, these levels have declined due to increased awareness and the implementation of regulatory controls. Others, such as PBDEs, have been detected in greater concentrations, although these substances are now regulated. Despite these exposure concerns, Health Canada promotes breastfeeding as the best method of feeding infants because its proven health benefits outweigh any potential risks.

The specific risk from typical infant exposure to toxic substances in breast milk is not well understood. The limited research that has been conducted in this area suggests, however, that exposure to toxic substances while in the womb may be of greater concern than exposure from breastfeeding, due to the greater vulnerability of the developing fetus. Other food for infants, including formula, is sometimes necessary. Standards and practices are in place to ensure the safe manufacture and use of these products. There are, however, still opportunities for contamination: if the formula is made with tap water, it could contain trace levels of toxic substances. Many public health units advise people who live in houses built before the mid-1950s, which may have lead service lines, to filter their drinking water before reconstituting baby formula.

Toxic Substances in Our Environment

OUTDOOR AIR

Air pollution affects many of Canada's urban areas where the population is concentrated, and is of particular concern during the summer months when smog is more frequent. Smog is a noxious mixture of vapours, gases and particles that contain toxic substances. It often appears as a yellowish-brown haze in the air. The principal ingredients of smog are ground-level ozone (O_3), nitrogen oxides (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), VOCs and particulate matter (PM).

Sources of the toxic substances found in outdoor air include steel manufacturers, petroleum refineries, fuel refilling stations, industrial and residential solvent use, paint application, manufacturers of synthetic materials, food processing, agricultural activities, emissions from automobiles and other forms of transportation, and wood burning. In forested rural areas, outdoor air quality can be significantly affected by forest fires.

For more information on outdoor air quality, see Pollution Probe's *The Smog Primer* at www.pollutionprobe.org/Publications/Primers.html

INDOOR AIR AND DUST

Toxic substances in the home are most commonly found in indoor air and in dust. The quality of indoor air is considered to be one of the top five environmental hazards to human health. It can deteriorate when measures to increase energy efficiency result in decreased ventilation and, therefore, higher concentrations of toxic substances. Indoor sources of some pollutants (e.g., lead) are of even greater concern than outdoor ones.

Transportation

Toxic substances may be emitted as part of vehicle exhaust. Some are present in gasoline and are emitted into the air when it evaporates or passes through the engine as unburned fuel. Benzene, for example, is a component of gasoline that may be emitted in small quantities during refuelling. Formaldehyde, acetaldehyde, and 1,3 butadiene are not present in fuel but are by-products of incomplete combustion and may also be emitted when driving. The interior of a car can also have elevated exposures: studies have shown that benzene levels can be higher inside a car than outside. The emissions of new vehicles have declined due to the development of more effective pollutant control devices and improved fuel formulations, but the impact of these improvements must be set against increases in the number of vehicles being driven. Canada regulates vehicle emissions under CEPA 1999.

For further information about automobile emissions, see Pollution Probe's *Primer on Automobile Fuel Efficiency and Emissions* at **http://www.pollutionprobe.org/pdfs/AutoPrimer.pdf**

Recent studies in the UK, Europe and the US have shown the presence of toxic substances originating from consumer products in indoor dust, including phthalates, polybrominated biphenyls and short-chain chlorinated paraffins. Other contaminants present in dust include residues of heavy metals (e.g., lead in household paint manufactured before 1978) and those present in outdoor soil and street dust carried indoors. Many chemicals used to make products durable, flexible, coloured, scented, stain-resistant and flame-retardant can become part of the indoor air or dust in houses where these products are regularly used. Dust can be a major exposure route for babies and children because they crawl and often put their fingers in their mouth.

DRINKING WATER

As a result of improper storage and disposal, toxic substances can make their way into the soil and eventually mix with groundwater. Toxic substances found in the air can also be deposited in the water table, and those from natural deposits in the earth may be present in groundwater. Poorly designed wells can allow precipitation and stormwater runoff to reach the water table without filtering through the soil. Proper well design and construction reduce the risk of water contamination by sealing the well from any surface contaminants. Industrial waste water may also be discharged into waterways and eventually make its way into our drinking water.

Water treatment and filtration plants have the ability to remove some of the contaminants regularly found in drinking water, such as iron, phosphorus, antimony and arsenic. Chemical or non-chemical water treatments, such as chlorine, UV or ozonation, can create trace levels of toxic by-products in water. The toxic substance inorganic chloramine is created when chlorine and ammonia (sometimes found in waste water from industrial sources) are combined. Disinfection helps protect people from serious waterborne illnesses, and the benefits of easily available drinking water are usually considered to outweigh the risks.

For more information on drinking water in Canada, see **http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/index-eng.php**

For more information on drinking water in Ontario, see **http://www.ontario.ca/drinkingwater**

WORKPLACE EXPOSURE

In offices, exposure to toxic substances can come from products such as furniture, computers and lead paint or from the materials involved in manufacturing, such as potentially carcinogenic or endocrine-disrupting substances, organic solvents and mercury. The level of workplace exposure can be considerably higher than that experienced by the general population. Workers at aluminum smelting plants may be exposed to high levels of airborne fluoride, a by-product of aluminum production. A worker who is responsible for degreasing metal has an increased risk of acute toxic effects as a result of contact with solvents containing toxic substances. Studies have also shown that families of workers exposed to toxic substances can have higher exposure levels because contaminants are brought into the home on the worker's shoes and clothes. Occupational exposure can be harmful to the reproductive health of men and women. The use of protective safety equipment and the enactment of occupational health and safety legislation have helped to minimize these exposures.

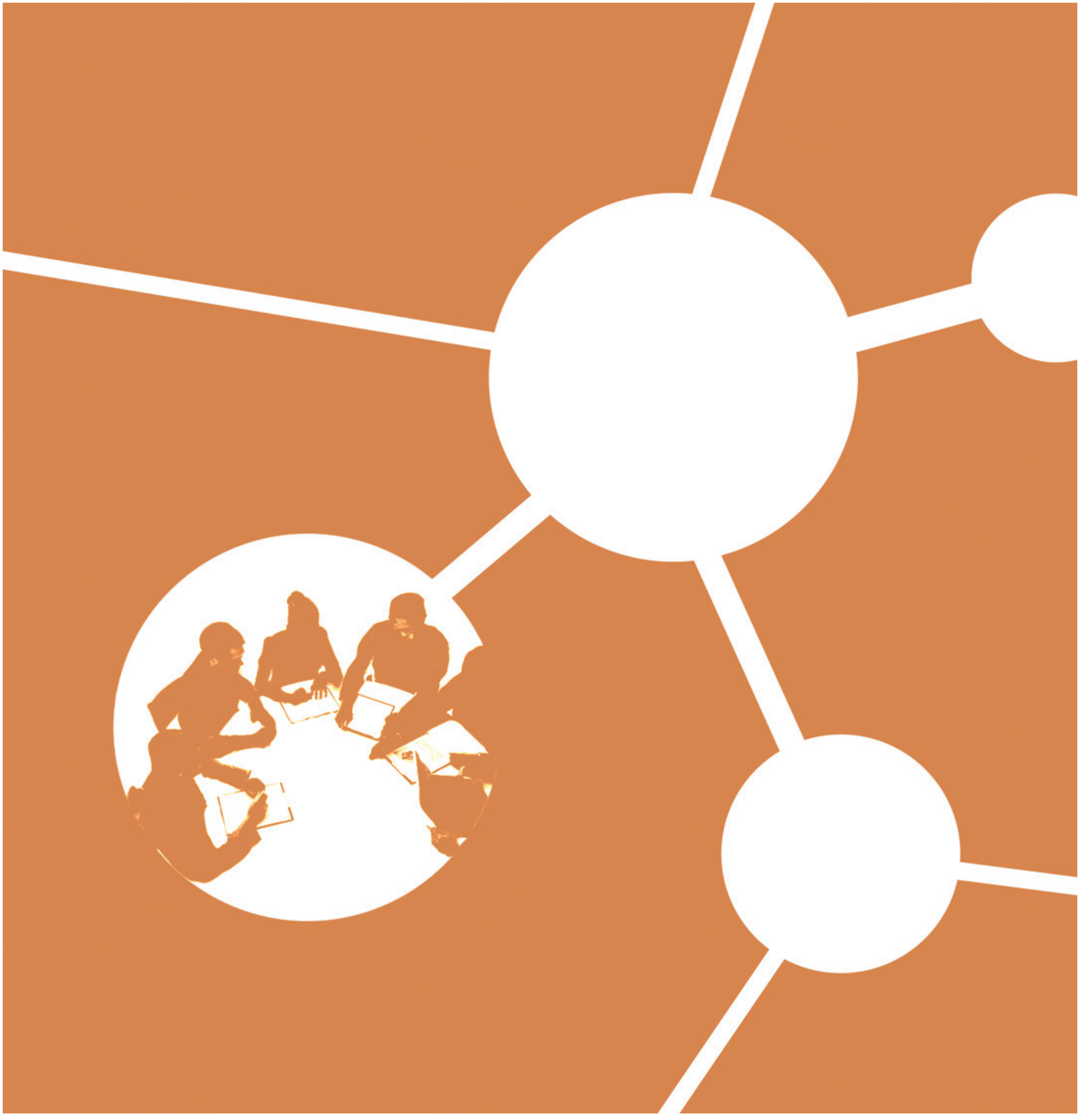
Challenges Ahead

While toxic substances were once mainly associated with industrial releases, the general public is increasingly aware that consumer products must also be regulated and managed. Legislation plays an important role in assessing toxic substances used in Canada, but it does not ensure the safety of all products imported into Canada. The new *Canada Consumer Product Safety Act* provides the government with increased powers to take imported products it considers dangerous, such as children's toys containing cadmium or lead, off the market.

Another challenge arises from the release of toxic substances that do not originate from a single source. For example, a toxic substance applied in a farmer's field can then make its way via soil erosion, groundwater infiltration or surface runoff into nearby tributaries or lakes. As the source of these releases can often be difficult to pinpoint, their management poses a significant challenge. While many jurisdictions have recognized the need to address non-point sources of toxic substances, strategies for doing so are still in development.

Summary

In this chapter, we traced the main paths of toxic substance release, and learned about those substances found in our natural environment and those that are released as a result of human activities. An understanding of the circumstances in which we may be exposed to toxic substances is key to understanding how to manage them and avoid exposure. Now that we know their potential sources and effects, what can we do about toxic substances? Various stakeholders are determined to ensure that toxic substances are properly managed. The contributions of one such stakeholder – the government – are discussed in the next chapter.



Chapter Five

WHAT IS THE ROLE OF GOVERNMENT?

Health Minister proposes new guideline on toxic metal in kids' jewelry – Ottawa Citizen, July 25, 2011

This chapter examines some of the regulations and management strategies used at the federal, provincial and municipal levels to deal with toxic substances, as well as some of the international initiatives in which Canada takes part. As the processes differ from province to province and between municipalities, a detailed look at local engagement is beyond the scope of this primer. What follows is a brief overview of some of the key legislation used to assess and manage toxic substances in Canada.

With regard to toxic substances, government has assumed the following responsibilities:

- to promote the advancement of knowledge
- to assess changes to our health and that of the environment
- to set and enforce law
- to promote good practices
- to inform the public
- to address international obligations
- to coordinate work between jurisdictions

These measures require ongoing review and adjustment to incorporate new knowledge about effects and new substances.

Government of Canada

The main federal legislation for protecting human health and the environment from the potential risks associated with toxic substances is CEPA 1999. It governs many aspects of the assessment and legislation of toxic substances throughout their life cycles. Other key federal acts are the *Food and Drugs Act*, *Pest Control Products Act*, *Canadian Fisheries Act*, *Hazardous Products Act* and *Canada Consumer Product Safety Act*. The Chemicals Management Plan (CMP) is a national program that addresses the potential risks posed by chemicals, including those that came onto the market before the implementation of pre-market assessments in 1994. The CMP is guided by the Toxic Substances Management Policy, which ensures that federal programs are consistent with the government's main objectives. The National Pollutant Release Inventory (NPRI) is a publicly accessible inventory of pollutant releases in Canada and provides information that can be used by the government for assessment and management purposes.

Assessment of Toxic Substances

In Canada, the federal government decides which chemicals can enter the market. With the initial implementation of CEPA in 1988, the approximately 23,000 substances that were manufactured, imported or used in Canada for commercial purposes between 1984 and 1986 were defined as "existing" substances. These substances made up the federal Domestic Substances List (DSL). Any substance not on the DSL is considered a "new substance."

When the DSL was introduced, most of the substances it included were "grandfathered in," without the assessment process that would later be developed for CEPA 1999. Health Canada and Environment Canada worked together to identify and prioritize these substances based on hazard characteristics, completing their categorization in 2006. Approximately 4,300 substances on the DSL were identified as requiring further evaluation, including risk assessment.

New substances entering the market must undergo screening according to the *New Substances Notification Regulations (Chemicals and Polymers)* or *New Substances Notification Regulations (Organisms)* of CEPA 1999 to assess their potential toxicity. If a substance meets all the requirements for the applicable regulation, it may be used commercially at specified levels; however, it will not be added to the DSL until a further review and risk assessment determines that there is no suspicion of it being toxic. It is estimated that an average of 525 notifications of new substances are submitted each year, and approximately 200 substances approved and added to the DSL, which now includes more than 26,500 substances. These substances may be subject to reassessment if new information becomes available, if the conditions of use change or if new legislation is introduced.

Substances that are found to be toxic according to CEPA 1999 are recommended for inclusion in the List of Toxic Substances. Once a substance is placed on this list, a management plan is established for its use, disposal or possible phase-out. At present, there are 96 individual substances and families of substances on the list.

Management of Toxic Substances

Strategies for the management of toxic substances include identification, assessment and risk control. The assessment of risk can involve determining the margin of safety between an actual exposure and an exposure that could result in an adverse effect. Based on the results of the assessment, the government identifies the risk management control options that are most appropriate. Other factors, including cost and societal impact, must also be taken into account.

Under CEPA 1999, once a new substance is suspected of being toxic, the government may

- permit manufacture and import, subject to certain conditions
- prohibit manufacture or import for up to two years
- prohibit manufacture or import pending government assessment

Substances that are prohibited or subject to conditions cannot be placed on the DSL and must be reported to the government by any new manufacturer or importer.

For more information on socio-economic considerations in the management of toxic substances, see **http://www.tbs-sct.gc.ca/ri-qr/directive/directive00-eng.asp**

Toxic Substance Regulation in the United States

The *US Toxic Substances Control Act* (TSCA), passed in 1976, establishes restrictions and reporting, record-keeping and testing requirements for toxic substances. The TSCA includes an inventory of toxic substances that currently stands at approximately 84,000 substances: 61,000 are considered "existing" and more than 19,000, "new" (i.e., assessed after 1979). As was the case in Canada, many existing substances were grandfathered in without a comprehensive risk assessment. The TSCA is under review and has been criticized by many stakeholders for being ineffective. The US Environmental Protection Agency estimates that there are between 9,000 and 15,000 chemicals on the market in the United States today and that approximately 700 new substances are added each year.

CHEMICALS MANAGEMENT PLAN, 2006

The Chemicals Management Plan, announced in December 2006, assessed the more than 4,300 chemicals identified under the CEPA 1999 categorization process as requiring further review. This process resulted in the addition of more substances or substance groups to the List of Toxic Substances. Also included in the plan was an initiative called "The Challenge": the government requested industry to provide information on 200 high-priority substances to help in its assessments.

The Government of Canada has also taken action to control, and in some cases prohibit, certain substance categories, such as flame retardants, confirmed to be harmful to the environment and to human health in the long run. Some substances that are no longer available in the Canadian market are subject to Significant New Activity (SNAc) provisions, which require that any proposed new manufacture, import or use of these substances be submitted to risk management and further risk assessment.

TOXIC SUBSTANCES MANAGEMENT POLICY, 1995

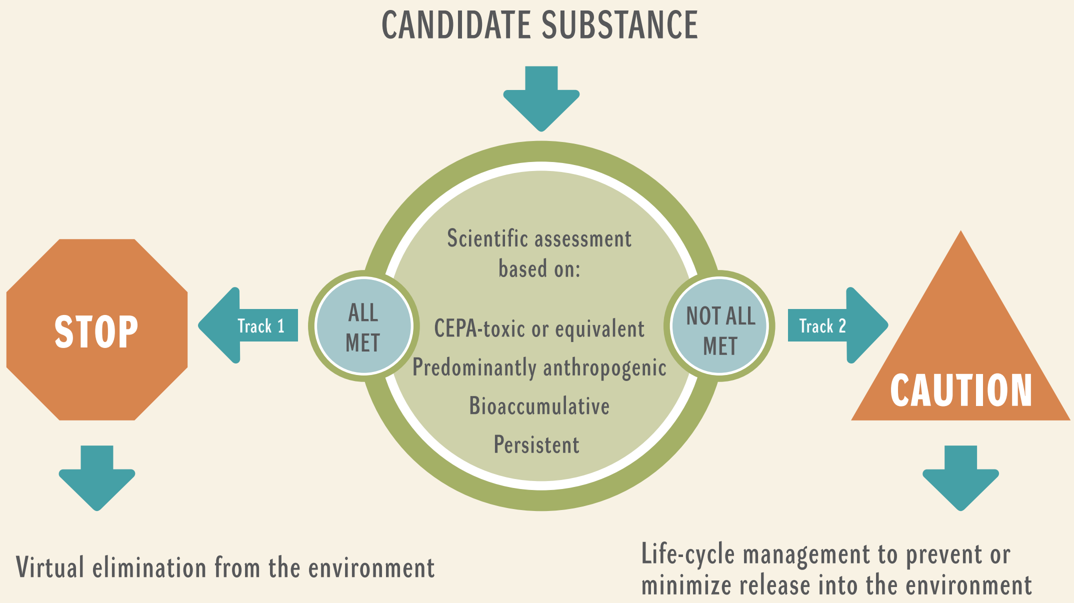
The Toxic Substances Management Policy provides two main tracks for dealing with those substances included in the List of Toxic Substances:

VIRTUAL ELIMINATION (TRACK 1) – applies to substances that are considered toxic according to CEPA 1999, predominantly anthropogenic (the result of human activity), persistent and bioaccumulative. These substances are targeted for virtual elimination by addressing the sources of release and by removing or managing the substance if it is already in the environment. The burden of proof rests with the user or generator to show that there will be no release of a measurable quantity at any point in the substance's life cycle.

LIFE-CYCLE MANAGEMENT (TRACK 2) – requires the treatment and management of substances throughout their entire life cycles. Management strategies include pollution prevention plans, use restrictions, codes of practice and voluntary environmental performance agreements.

Many Track 1 and Track 2 substances are already subject to other federal statutes such as the *Pest Control Products Act* and the *Food and Drugs Act*, and, where this is the case, they are managed under the appropriate program.

Figure 5-1: Canadian Federal Toxic Substances Management Policy



Adapted from: Environment Canada, Toxic Substances Management Policy, 1995
Available at http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=2A55771E-1

Perfluorooctane Sulfonate (PFOS), Its Salts and Its Precursors – An Example of a Substance on the Virtual Elimination List

Perfluorooctane sulfonate (PFOS) is a synthetic chemical belonging to a large class of compounds that have extremely strong carbon-fluorine bonds. These bonds account for its stability and unique properties. PFOS was used as a water, oil, soil and grease repellent for carpets, fabric, upholstery and food packaging, as well as a surfactant in firefighting foams, aviation hydraulic fluids and metal plating. Since 2002, PFOS has been voluntarily phased out of production in Canada, and annual imports are now limited. Existing stockpiles are limited to aqueous film-forming foam used for fighting fuel fires.

PFOS, along with its salts and precursors, is one of two toxic substances on Canada's Virtual Elimination List. It is persistent and bioaccumulative, and has been found at levels that are harmful to wildlife, including polar bears and some bird species. PFOS appears to bind to protein rather than fatty tissue. Current exposure for humans is not significant enough to be considered dangerous to human health, but further research in this area is necessary.

NATIONAL POLLUTANT RELEASE INVENTORY

The NPRI is Canada's inventory of pollutant releases (to air, water and land), disposals and transfers for recycling. As of 2009, 347 substances or substance groups were listed on the NPRI, including most of those on the CEPA 1999 List of Toxic Substances. While substances on the NPRI are considered to be of concern for human health and the environment, not all are toxic according to the criteria of CEPA 1999. Companies that meet certain requirements must report the release of substances on the NPRI annually to Environment Canada. This information is made publicly available and helps the government to track the progress of pollution prevention strategies and risk management measures.

Other Standards and Legislation

NATIONAL AMBIENT AIR QUALITY OBJECTIVES

Canada's National Ambient Air Quality Objectives (NAAQOs) are based on recommendations from the CEPA National Advisory Committee (NAC) Working Group on Air Quality Objectives and Guidelines. NAAQOs set benchmark levels of protection and national goals for air quality, and provide guidelines for other levels of government in the development of corresponding risk management strategies. NAAQOs are currently being reviewed and may be replaced by Canadian Ambient Air Quality Standards (CAAQS) under the proposed federal Air Quality Management System (AQMS). AQMS is a new collaborative system of air quality management that builds on existing federal, provincial and territorial initiatives to manage air quality.

For further information on the AQMS, see http://www.ccme.ca/ourwork/air.html?category_id=146

Toxic Substance Regulation in the European Union

The European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Program is one of the most encompassing toxics regulations to date, replacing more than 40 existing EU laws. Under REACH, existing and emerging substances are reviewed and assessed under a single system. The intent is that no chemical under REACH will be permitted to enter the market until the company producing it has proven that it is safe. This differs from other chemicals policies in that the burden rests on industry to develop risk information and determine what management measures should be pursued before the substance can enter the market. Known toxics are phased out and replaced with safe substitutes where possible. It is estimated that today there are more than 30,000 existing chemicals on the European market and that these chemicals account for more than 99 per cent of the total volume of substances available.

The EU currently has eight substances on the Authorisation List of Substances of Very High Concern, which means that they may not be placed on the market or used without special authorization. In addition, more than 50 substances are under consideration.

CANADA-WIDE STANDARDS

Canada-wide standards (CWSs), developed by the Canadian Council of Ministers of the Environment, address key environmental protection and health risk issues throughout the country. Jurisdictions work together to develop appropriate standards for individual contaminants or issues. Some of the current CWSs deal with benzene, dioxins and furans, petroleum hydrocarbons in soil, and mercury. CWSs related to air quality are currently under review and may be replaced by the proposed AQMS.

CANADIAN FISHERIES ACT

The *Canadian Fisheries Act* is a federal law dealing with the management and monitoring of fisheries, the conservation and protection of fish and their habitat, and pollution prevention. Section 36 of the Act prohibits the deposit of harmful substances (e.g., effluent from petroleum refineries, pulp and paper industries, and metal mining) in the aquatic environment.

HAZARDOUS PRODUCTS ACT

The *Hazardous Products Act* (HPA), administered by Health Canada, gave the federal government broad powers to prohibit or regulate products that it considers to be, or likely to be, a danger to the health or safety of the public. Under HPA, a product may not be imported, advertised or sold if it does not meet certain requirements. The scope of HPA changed with the introduction of the *Canada Consumer Product Safety Act* in June 2011 (see below). Products used in the workplace continue to fall under the regulatory authority of the HPA.

For more information on the *Hazardous Products Act*, see **http://laws-lois.justice.gc.ca/eng/acts/H-3/index.html**

CANADA CONSUMER PRODUCT SAFETY ACT

The *Canada Consumer Product Safety Act* (CCPSA) replaced Part 1 and Schedule 1 of the *Hazardous Products Act* and introduced a more stringent regulatory regime for consumer products. The Act recognizes that suppliers of consumer products have an essential role to play in addressing any concerns posed by their goods. The mandatory reporting provision (Section 14) is a proactive and efficient response to the potential effects of any ingredients in products. By requiring reports of incidents, the government is able to monitor more effectively the actions taken by manufacturers and importers to minimize risks. The CCPSA gives the federal government the authority to take swift corrective action, including mandatory recalls, when a product requires further investigation. The Act's general prohibition against the supply of consumer products that pose an unreasonable risk to human health or safety allows for prompt and effective action once a risk has been identified, which was not possible for products previously regulated under HPA.

For more information on the *Canada Consumer Product Safety Act*, see **http://www.hc-sc.gc.ca/cps-spc/legislation/acts-lois/ccpsa-lcspc/index-eng.php**

Government of Ontario

In Ontario, most of the provincial legislation pertaining to toxic substances is overseen by the Ministry of the Environment. The Ministry publishes air quality standards and guidelines for over 300 substances. Under the *Clean Water Act 2006*, safety standards have been introduced to protect present and future sources of drinking water from toxic substances and pollutants. Ontario has also implemented the Municipal Industrial Strategy for Abatement (MISA), which regulates industrial discharges and other contaminant discharges to water according to nine regulations of the *Ontario Water Resources Act* (OWRA). The OWRA also governs broader contaminant discharges to Ontario's natural water sources. The Ministry requires that hazardous wastes, manufacturing residues (contaminated wastes and complex chemicals), biomedical wastes from the healthcare sector, pesticide runoff, discarded batteries and electronic equipment be safely collected, stored, transported, treated and disposed of. These wastes require special handling to reduce possible exposure. The management of hazardous waste falls under the province's *Environmental Protection Act* and *Ontario Regulation 347*.

In 2008, the province approved two new industry-funded waste diversion programs under the *Waste Diversion Act*: the Municipal Hazardous and Special Waste Program (to recycle or dispose of hazardous wastes generated by households) and the Waste Electrical and Electronics Equipment Program (to collect and recycle computers and electronics). These programs will help to ensure that toxic substances, including lead, mercury and cadmium, will be kept out of landfills.

For more information on the *Environmental Protection Act* and *Regulation 347*, see **http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900347_e.htm**

TOXICS REDUCTION STRATEGY

Ontario's Toxics Reduction Strategy, modelled on the *Massachusetts Toxic Use Reduction Act*, has three primary elements:

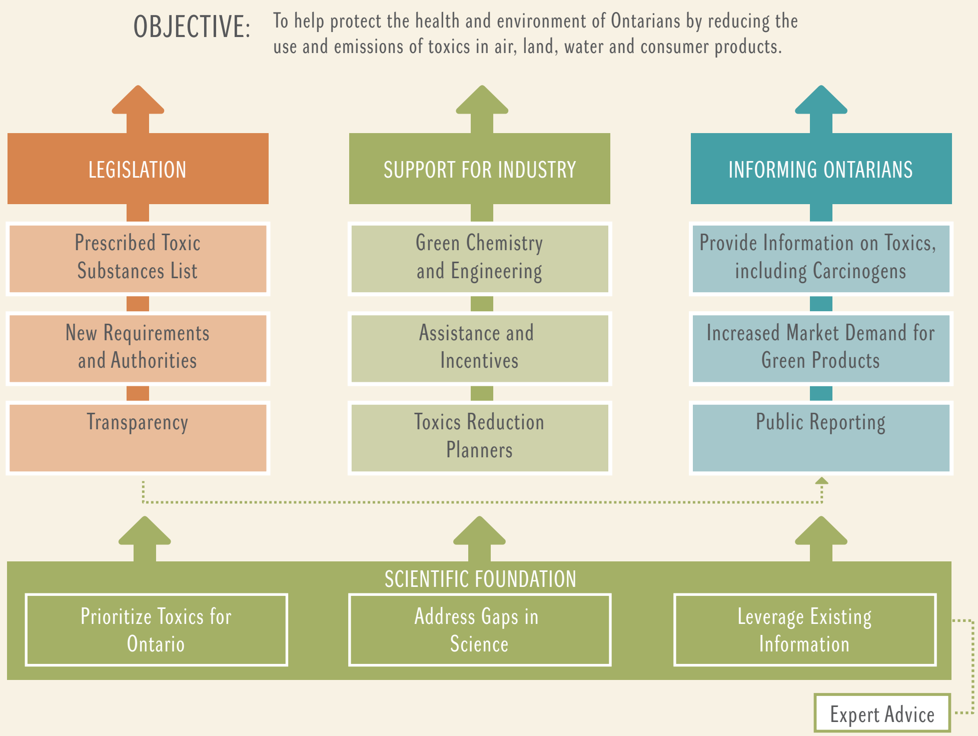
- managing and reducing the creation, use and release of toxic substances to improve the protection of the environment and human health
- informing Ontarians about toxic substances in their communities
- helping to ensure that Ontario is well positioned to compete in an increasingly green global economy

The *Toxics Reduction Act* (TRA) is the cornerstone of the Strategy. It requires facilities to track and quantify toxic substances and to make plans to reduce their creation, use and release. The TRA includes all of the substances in the federal NPRI, plus acetone (*Ontario Regulation 127/01*). During Phase 1 of the implementation of the TRA, the province prioritized 47 substances and substance groups for immediate action based on their potential for environmental and human health effects and emissions. Phase 2 will address the remaining 300 substances. Information collected through reporting requirements will be made available to the public to raise awareness of toxic substances and, where applicable, the actions taken to reduce their release into the environment.

The *Massachusetts Toxic Use Reduction Act*

The *Massachusetts Toxic Use Reduction Act* (TURA), passed in 1989, requires companies using large quantities of toxic substances to develop and implement pollution prevention plans and to report the results annually. Under TURA, Massachusetts is committed to reducing the generation of toxic waste by 50 per cent. This was accomplished by 1998. TURA was one of the first acts to focus on use reduction rather than waste management as the preferred method for achieving compliance with government regulations.

Figure 5-2: Ontario Toxics Reduction Strategy



Adapted from Ontario's Toxics Reduction Strategy
Available at www.cec.org/Storage/84/7935_9_Mayes_Toxics_MOE.pdf

BROWNFIELD REGULATIONS

In the last century, many industries in Ontario operated within the city core and along waterways. Many of these mills, factories, railway yards and service stations have closed or relocated. "Brownfields" refers to the lands left behind, which lie idle and may be contaminated with toxic substances but have the potential for redevelopment. Cleaning brownfields helps the environment and promotes the reuse of land close to public transportation and other services, thus discouraging encroachment on new green spaces for development. *Ontario Regulation 153/04*, which covers brownfields, was amended in 2011 to

- ensure that there is a record of the integrity of the site
- make generic risk assessments more cost-effective and efficient
- strengthen environmental site condition standards

CERTIFICATES OF APPROVAL

Any facility that releases emissions to the atmosphere, discharges contaminants to ground or surface water, provides potable water supplies, or stores, transports or disposes of waste must have a Certificate of Approval. The Ontario Ministry of the Environment examines each facility proposal, through the certification process, to ensure that the environment is not adversely affected. Each Certificate of Approval

- addresses matters that fall within the mandate of the Ministry
- focuses on site-specific characteristics relevant to each proposal
- contains enforceable requirements for each facility to ensure the protection of human health and the natural environment

Certificates of Approval are used by Ministry staff to ensure that the operation of facilities complies with environmental laws. The public has online access to a list of certified facilities.

The Ministry recently announced that it will be implementing a new process to streamline environmental approvals, using a risk-based approach: Certificates of Approval will be replaced with Environmental Compliance Approvals.

For more information on this proposed regulatory amendment, see **http://www.ene.gov.on.ca/environment/en/industry/assessment_and_approvals/modernization_of_approvals/STDPROD_075525**

AIR QUALITY

Ontario Regulation 419/05: Air Pollution – Local Air Quality protects communities from adverse effects of industrial contaminants, including toxic substances, from local sources. Under this Regulation, data on air emissions from facilities are compiled, and the impact of these emissions on the environment is assessed against the Ministry of the Environment's air standards.

WATER STANDARDS

A supply of safe, high-quality drinking water is a key factor in maintaining public health. Legislation to support a safe water supply includes the following:

- ***Safe Drinking Water Act*, 2002**: This Act provides regulations for drinking water systems and testing to protect human health and the environment.

- ***Ontario Clean Water Act*, 2006:** Through this Act and its regulations, local source-protection committees have been established to assess existing and potential hazards to their water supply, including those from toxic substances. Local source-protection plans must include public input, and communities are empowered to take actions, based on sound scientific evidence, to deal with hazards that have been identified.

PESTICIDES

The Cosmetic Pesticides Ban, implemented in April 2009, aims to reduce the unnecessary risks of pesticides used for cosmetic purposes. The province-wide ban supersedes local municipal pesticide bylaws. More than 95 pesticide ingredients are banned from cosmetic uses. Agriculture and forestry are exempt from the ban, as are golf courses subject to specific conditions. Pesticide use is still allowed in situations where it is essential to ensure public health or safety (e.g., to fight West Nile Virus).

Municipal and Regional Governments

While federal and provincial legislation provides the framework for addressing toxic substances in Canada, local governments are becoming more involved. The following are a few of the ways in which municipalities contribute to the management of toxic substances:

SEWER BYLAWS – Sewer bylaws set strict limits on heavy metals and toxic organic compounds in waste water discharged to sewers. These bylaws often require industries to identify ways to reduce or eliminate the discharge of pollutants, including toxic substances, at the source.

AIR QUALITY BYLAWS – Some municipalities have passed bylaws that assess and control the health effects of major emissions of pollutants, such as fine particulate matter (i.e., airborne particles less than 2.5 micrometres in size).

HOUSEHOLD HAZARDOUS WASTE DEPOTS – Many municipalities accept certain household wastes, including batteries, fluorescent light bulbs and antifreeze, in order to keep these wastes out of landfills. These programs will often provide directories of local businesses that take back materials, such as computer monitors, for reuse, recycling or disposal.

TORONTO CHEMTRAC PROGRAM

The aim of the City of Toronto's ChemTRAC program is to reduce the level of 25 toxic chemicals, which are, at present, a matter of concern in the environment. To meet this goal, the program

- requires local facilities to track and report their use, manufacture and release of the listed toxic substances
- provides resources to support businesses that use green business strategies or alternatives to these chemicals
- provides the public with reported data, information about the toxic chemicals and tips on reducing toxic substances at home

The substances covered by the program include benzene, cadmium, mercury, vinyl chloride and formaldehyde, which are used in a wide range of industries, including chemical manufacturing, food and beverage production, and automotive repair.

When designing the program, the City examined toxic substances present in the community, compiled best practices from other toxic reduction programs, and consulted with businesses, residents and community organizations. Its research showed that when a business was required to report on toxic substances, it would find ways to reduce their use.

International Initiatives

Given the ability of some toxic substances to travel long distances, it is necessary for governments worldwide to work together to minimize the associated impacts. The following is a list of some of the international initiatives in which Canada is a participant:

- **Canada-US Great Lakes Water Quality Agreement (1972, 1978 and 1987)** – This binational agreement reflects the two countries' commitment to resolving the water quality issues of the Great Lakes. The initial agreement, which focused on industrial point-source pollution, led to a dramatic reduction in many related pollution problems. A subsequent agreement, signed in 1978, adopted an ecosystem approach, and called for a broad range of pollution-reduction programs and the virtual elimination of persistent toxic substances (zero discharge). The two governments are currently negotiating to amend the Agreement to reflect current challenges in the Great Lakes.
- **Convention on Long-Range Transboundary Air Pollution (1979)** – Led by the United Nations Economic Commission for Europe, this was the first internationally binding instrument to deal with the problems of air pollution through scientific collaboration and policy negotiation.
- **Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal (1992)** – This global treaty implemented a control system for transboundary movements of hazardous waste and established environmentally sound management strategies to deal with the adverse effects of the generation, movement and management of this waste.

- **The Great Lakes Binational Toxics Strategy (1997)** – Like the Canada-US Great Lakes Water Quality Agreement (GLWQA), this strategy is aimed at reducing or eliminating persistent toxic substances, especially those that bioaccumulate in the Great Lakes. The future of this strategy depends on the outcome of the negotiations to amend GLWQA.
- **Stockholm Convention (2001)** – An international treaty to deal with persistent organic pollutants (POPs), the Convention initially targeted a "dirty dozen" persistent pollutants but has since added another nine to the list.
- **Rotterdam Convention (2004)** – This international convention promotes co-operation and shared responsibility in the international trade of hazardous chemicals. The Convention addresses increasing concerns about the potential risks posed by hazardous chemicals and the vulnerability of the many countries that lack an adequate infrastructure to monitor their import and use.
- **Strategic Approach to International Chemicals Management (2006)** – This policy framework, established by the International Conference on Chemicals Management, is designed to foster the sound management of chemicals throughout their life cycles.
- **Mercury Negotiations (2009)** – The Governing Council of the United Nations Environment Programme (UNEP) is currently leading negotiations to develop a global, legally binding instrument on mercury with the goal of minimizing and, where feasible, eliminating mercury releases.

Arctic Monitoring and Assessment Program (AMAP)

The Arctic Monitoring and Assessment Program (AMAP) was established in 1991 to implement some of the measures of the Arctic Environmental Protection Strategy (AEPS). AMAP's main function is to advise the governments of eight countries (Canada, Denmark/Greenland, Finland, Iceland, Norway, Russia, Sweden and the United States) on threats to the Arctic from pollution and associated issues. AMAP is responsible for assessing the effects of contaminants in the Arctic, and documenting trends, sources, pathways and impacts.

AMAP's main concerns include the effects of POPs and heavy metals on the Arctic environment and population, and the combined effects of pollutants and other stressors.

For further information related to AMAP, see **http://www.amap.no/**

Challenges Ahead

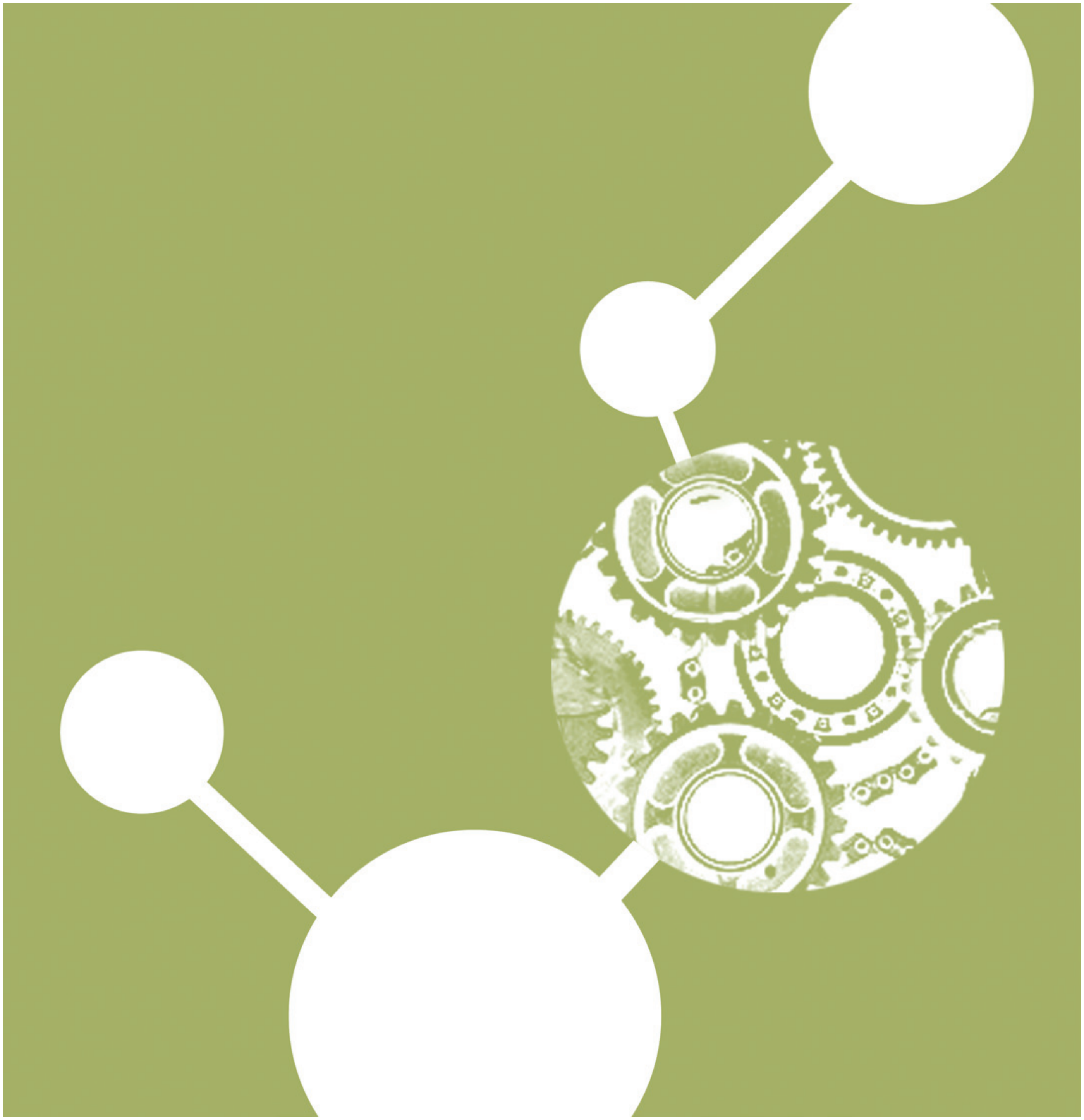
One of the most significant challenges for government is to ensure that toxic substance legislation evolves to incorporate improved scientific knowledge and address new and emerging concerns. At present, efforts to evaluate and regulate the risks associated with toxic substances tend to focus on one substance at a time. The ability to gauge the effects of multiple exposures is an important goal.

Regulatory agencies are confronted with the challenge of assessing and managing the many new substances that enter the market each year. There are still a number of substances in commercial use that have not been fully assessed – a process that takes time and relies on the coordinated efforts of various parties.

Transboundary movement of substances will continue to be a crucial environmental issue. As more toxic substances accumulate in places that straddle borders, such as the polar regions and the Great Lakes, there will be greater need for concerted efforts on the part of governments worldwide to minimize the associated impacts.

Summary

In this chapter, we described the role that governments in Canada have played in the identification, assessment and management of toxic substances. We reviewed a few of the main acts and regulations that address toxic substances, and Canada's participation in international agreements. Now we will turn our attention to the role that industry plays in addressing the use, release and disposal of toxic substances. Many companies have introduced green technologies and replaced toxic substances with safer alternatives.



Chapter 6

WHAT IS THE ROLE OF INDUSTRY?

Toxic emissions down; Dofasco, Stelco praised for taking lead – The Hamilton Spectator, July 26, 2000

This chapter outlines some of the innovations in industry that are helping with the management of toxic substances and their release. It then looks at management strategies already in use to help protect and inform the public, including recycling and environmental labelling. This is followed by a discussion of select industry reporting requirements under the Canadian Environmental Protection Act*, the Ontario Toxics Reduction Strategy and Toronto's ChemTRAC program. Finally, the chapter examines some voluntary industry groups and their involvement in toxic substances management.*

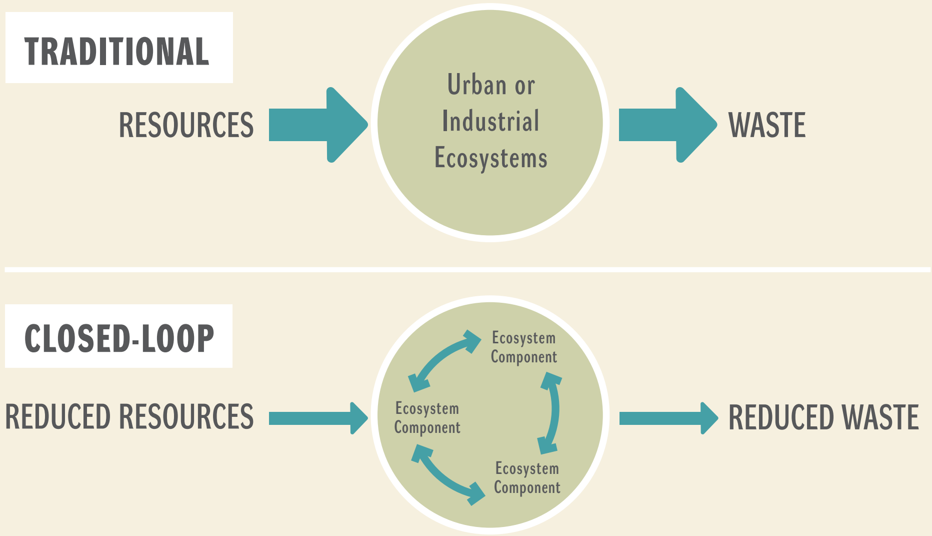
As a major user and creator of toxic substances, industry has a responsibility to understand how they are used and handled, reduce risks of exposure, and seek safer alternatives. It can play a crucial part in forming a holistic understanding of toxic substance use and in determining where reduction and elimination are appropriate or possible. In discussions with government, industry is consulted on toxic substance policies, provides information and critiques, identifies opportunities for reduction, and reports on the creation, use and disposal of these substances. Because of its capacity and expertise, industry plays a major role in the development and implementation of strategies to reduce the risks associated with the use of toxic substances.

Innovations

> When I think of what could be, I visualize an organization of people committed to a purpose and the purpose is doing no harm. I see a company that has severed the umbilical cord to Earth for its raw materials, taking raw materials that have already been extracted and using them over and over again, driving that process with renewable energy.
>
> Ray Anderson, founder of Interface Inc., a major manufacturer of modular carpet. Since 1995, Interface has reduced its ecological footprint by one-third. Its goal is to be sustainable by 2020.

Early concerns about toxic substance emissions focused on the point of discharge; however, because end-of-pipe solutions can be costly and are sometimes ineffective, attempts to reduce releases throughout the manufacturing process have become increasingly popular. Now, to a much greater degree, industry takes into account the environmental impact of a product throughout its entire life cycle and works toward a closed-loop system, where waste is recovered and redirected back into the process.

Figure 6-1: Traditional vs. Closed-Loop Industrial Process



Adapted from Cote, et al., *Industrial Ecology and the Sustainability of Canadian Cities*, 2006, p. 9.

End-of-Pipe Controls

End-of-pipe controls are treatments of effluent, solid waste or polluted air before its release into the environment. These controls focus entirely on the last stage of the industrial process. Many of the current means of dealing with the release of toxic substances are end-of-pipe fixes rather than new technologies capable of ensuring a smaller environmental footprint. That being said, there has been a push to create new end-of-pipe solutions that are more effective in treating emissions and discharges.

"Best available technology" (BAT) refers to a management strategy that is used in the development of anti-pollution measures. It promotes the adoption of the most effective and advanced techniques that are commercially available and economically sustainable. Government regulations and standards often require BATs in new facilities to limit polluting discharges. BATs for environmental performance are proposed in the current Canada-Wide Standards for Dioxins and Furans.

Abatement technologies are also widely used to deal with the capture and treatment of toxic substances before they are released into the environment, and recent innovations have increased their effectiveness. These technologies use physical, chemical or biological mechanisms to reduce emissions of toxic substances.

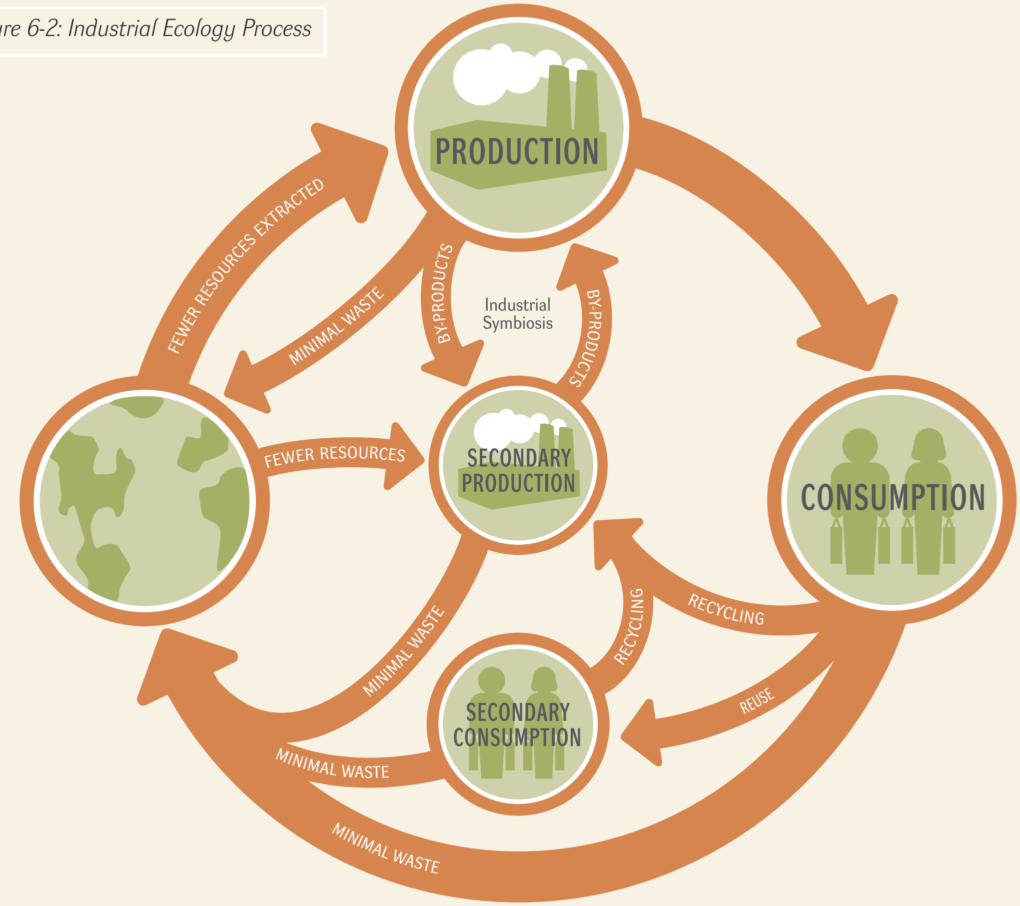
Industrial Ecology

Industrial ecology seeks to transform the current industrial system by placing it within, and modelling it after, natural systems. It proposes that groups of companies emulate the interactions of living organisms in an ecosystem. The flow of energy, resources and wastes in modern industry should correspond to an "...ecological system [which] operates through a web of connections in which organisms live and consume each other and each other's waste" (Garner and Keoleian, *Industrial Ecology: An Introduction*, 1995, p. 31).

Industrial ecology promotes a cyclical, rather than linear, system, where materials are reused as energy or raw materials for another product. Companies work together: the wastes generated by one may act as a raw material for another. The excess steam from an electrical generating facility could be used as a heat source for a nearby chemical manufacturer. Companies working together become more efficient and produce less waste than each in isolation. The Partners in Project Green: A Pearson Eco-Business Zone, at Pearson Airport near Toronto, is a practical example of industrial ecology, where businesses are working together through resource- and knowledge-sharing to reduce their collective environmental footprint. Figure 6-2 illustrates the industrial ecology process.

For more information on the Pearson Eco-Business Zone, see **http://www.partnersinprojectgreen.com/**

Figure 6-2: Industrial Ecology Process



Adapted from the International Society for Industrial Ecology
Available at www.is4ie.org/

Green Chemistry

Green chemistry aims to reduce pollution and toxic substances, increase efficiency, and limit the use of potentially harmful materials in the manufacture and use of chemicals. In its efforts to develop safer and more environmentally benign chemicals, green chemistry looks at the entire life cycle of a product to determine whether changes are possible in the design, manufacture or application processes. It has been applied to a range of products, including paints, dyes, textiles, adhesives, agrochemicals, paper, pharmaceuticals, plastics and bulk chemicals.

Green chemistry promotes toxics use reduction (i.e., reducing or eliminating toxic substances at the source) through decreasing emissions and limiting the reliance on toxic substances in the manufacture and use of chemicals. Current areas of study include biologically derived chemicals, renewable raw materials, green methods, and green products such as solvents and reagents.

GREEN CENTRE CANADA

Green Centre Canada is a not-for-profit organization that brings together researchers and industry partners in the attempt to move green chemistry ideas from the lab to the marketplace. The centre assumes the financial risks associated with developing early-stage innovations in green chemistry. These can include the costs of acquiring engineering and construction materials, and establishing energy production, chemical manufacturing, transportation and communication systems.

Dioxins and Furans

Dioxins and furans are the more than 200 chlorine organic compounds that are formed as unwanted by-products in combustion processes when traces of chlorine are present. They are considered persistent, bioaccumulative and inherently toxic. Some members of the dioxin and furan family are carcinogens, suspected endocrine disruptors and suspected developmental and reproductive toxicants. Their potential effects on humans and animals include skin disorders, liver problems, cancer, and impairment of the immune, endocrine, nervous and reproductive systems.

Dioxins and furans are released through iron and steel production, fuel burning (including diesel), electrical power generation and tobacco smoke. Dioxins can also be released through natural processes, including forest fires and volcanic eruptions. These substances make their way through the food web because they store easily in fatty tissue. An estimated 90 per cent of human exposure to dioxins is through diet.

The Government of Canada has created guidelines to minimize the release of dioxins and furans from municipal solid waste and hazardous waste incinerators, as well as regulations requiring the virtual elimination of dioxin and furan releases from pulp mills and pest control products. These efforts have led to a significant decrease in releases since 1990.

Consumer Products

Another innovative approach to toxic substance reduction aims to find new uses for products at the end of their life cycle. This "cradle to cradle" approach is becoming increasingly popular. When a product is being designed, it is important to consider its recycling potential. If products contain toxic substances such as brominated flame retardants and some heavy metals, there can be environmental and human health effects associated with disposal or recycling.

There are now certification standards that help consumers identify products that have been designed with the health of humans and the environment in mind. Such products use and reuse safe raw materials and substitute more benign chemicals where possible.

Recycling of Toxic Substances

Recycling in its simplest form reduces waste disposal, conserves natural resources, extends the life of certain materials and reduces the stress on landfills. It is, therefore, capable of playing an important role in the move toward reducing the impacts of toxic substances. "Producer responsibility" is a term that has become increasingly popular in discussions of the recycling and disposal of consumer products. It refers to the assumption of physical and financial responsibility for discarded products on the part of their manufacturers. Producer responsibility leads to pre-emptive waste management strategies, like "polluter pays," (the party responsible for polluting must pay for potential damages done to the environment) and increased motivation to improve the environmental design of products.

Stewardship Ontario's Orange Drop, a program for hazardous and special waste, has benefited from industry collaboration. The program provides accessible collection sites for wastes such as paints, solvents, single-use batteries and pesticides. Though many municipalities had established sites to collect these wastes, as of 2008, the companies that manufacture or import products that result in these wastes have been required to assume the costs of transporting and processing wastes returned to municipal or retail locations. Stewardship Ontario sets the fees, and industry decides whether to absorb the cost or charge consumers at the point of purchase.

For more information on the Orange Drop program, see **http://www.makethedrop.ca/**

Electronic Waste and Toxic Substances

"Electronic waste" or "e-waste" refers to discarded, surplus, obsolete or broken electrical or electronic equipment. It is one of the fastest-growing types of hazardous waste worldwide. Hazardous materials, including lead, cadmium, mercury, brominated flame retardants and other toxic substances, are found in e-waste alongside sought-after raw materials. Gold, copper coils, aluminum and other metals can be extracted and resold, but the process of extraction often involves melting, which releases arsenic, mercury and lead into the environment. Some of the e-waste collected in industrial countries is exported to developing countries, where regulations are less strict and recycling methods are often extremely hazardous to human health and the environment. It is imperative to continue to address the source of the problem – the design of electronic products and their export for disposal.

Environmental Labelling

Many consumers, concerned about the environmental performance of their purchases, have demanded more detailed information about their production. Industry has the option to convey the environmental benefits of its products through labelling.

There are now a range of logos and other labels that help consumers make more informed decisions related to the environment. Eco-labels may be

- self-managed or third-party-managed
- verified in-house or independently certified
- based on the product life cycle or a single attribute
- available for single or multiple sectors or product categories
- designed to demonstrate environmental leadership or relative performance, or to provide information

The value of any environmental claim rests on the assurance that the information is credible, objective, easily identifiable, and understood by consumers. Standards, which are voluntarily adopted by businesses, can help to ensure responsible claims in industry by requiring consistency in terms and application. ISO standard 14021, *Environmental labels and declarations – Self-declared environmental claims (Type II environmental labelling)*, published by the International Organization for Standardization in 1999, specifies requirements for environmental claims and labels. This international standard was adopted as a National Standard of Canada in 2000. Additional guidelines for best practices in eco-labelling based on ISO 14021 can be found in PLUS 14021, *Environmental claims: A guide for industry and advertisers*, published in 2008 by the Canadian Standards Association (CSA) and the Competition Bureau Canada (CB).

An eco-logo label gives consumers an indication of the environmental preferability of a product based on life cycle considerations and environmental performance against a set of criteria (e.g., top 20 per cent in class). It is important to bear in mind that eco-labelling programs do not assess all products available in the marketplace; there may be equally “green” products that have not been tested or certified.

For more information on PLUS 14021, see **http://www.csagroup.org/%5Crepository%5Cca%5CPLUS_14021-08EN.pdf**

Regulatory Reporting Requirements for Industry

Federal Reporting Requirements

There are many federal reporting requirements for chemical substances. Under CEPA 1999, any individual or business that intends to import or manufacture a new substance (i.e., one not included on the DSL) must submit a New Substance Notification package. The process (the type of information required, the timeline for reporting) depends on various factors, including the type of substance, the quantity that will be imported or manufactured, the intended use and the circumstances associated with its introduction. This information is used by Environment Canada to conduct a risk assessment before the substance is allowed on the market.

For further information related to New Substance Notification reporting requirements, see **www.ec.gc.ca/subsnouvelles-newsubs/default.asp?lang=En&n=ED6ABB02-1**

For further information related to industry-specific reporting, see **www.ec.gc.ca/subsnouvelles-newsubs/default.asp?lang=En&n=C9ECF2A3-1**

For further information related to reporting requirements for NPRI, see **www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=629573FE-1**

Provincial Reporting Requirements

Ontario's *Toxics Reduction Act* sets out reporting requirements for facilities regarding the use, creation and release of NPRI substances and acetone (*Ontario Regulation 127/01*). The Act requires annual reports from facilities in the manufacturing and mineral processing sectors that are already required to report to the NPRI or the Ontario Ministry of Environment under the regulation for acetone. The reports allow for a complete picture of the life cycle of a substance: how it enters a process, what happens to it during that process, how it leaves the process and what happens once it has been released.

For further information regarding reporting requirements for the *Toxics Reduction Act*, see **www.ene.gov.on.ca/en/toxics/about.php**

Municipal Reporting Requirements

As mentioned, Toronto's ChemTRAC program requires industry reporting on 25 toxic chemicals of priority concern to human health. Facilities within the City of Toronto that use or release one or more of these substances in excess of established thresholds must supply reports. The ChemTRAC program requires reporting at thresholds that are significantly lower than those of other levels of government in order to elicit reports from small and medium-sized organizations that are not currently required to report under the NPRI.

For further information regarding mandatory and voluntary reporting requirements under the ChemTRAC program, see **http://www.toronto.ca/health/chemtrac/index.htm**

Voluntary Industry Groups and Programs

Responsible Care®

The Responsible Care® program was launched in 1985 by the Chemistry Industry Association of Canada (formerly the Canadian Chemical Producers' Association). Its aim is to identify and eliminate harm associated with a product through environmental protection, resource conservation, occupational health and safety, process safety, research and development, transportation, product stewardship, purchasing, security and social responsibility. To meet the Responsible Care® codes, companies must achieve minimum standards; follow guidelines and checklists; form networks of company experts and leadership groups; submit tracking, analysis and performance reports; and continually update successful practices. This program is now active in over 50 countries.

As a condition of Responsible Care® membership, companies must help communities understand the types of emissions from their facilities and must respond to any relevant concerns voiced by the public or government. Since the launch of the program, members have helped reduce toxic substance emissions significantly.

For more information about Responsible Care® in Canada, visit **www.canadianchemistry.ca/ResponsibleCareHome.aspx**

Ontario BioAuto Council

The Ontario BioAuto Council is an industry-led, not-for-profit organization established in 2007 with funding from the Province of Ontario. Working closely with the provincial and federal governments, the Council connects chemical, plastic, and auto parts manufacturing companies with agriculture and forestry, in order to accelerate the commercialization of new technologies and build demand for affordable, sustainable, bio-based (i.e., composed of biological materials) products. It has been recognized internationally for its success in promoting new products that offer greenhouse gas and toxic substance emission reductions, including light-weight vehicle parts made from forest biomass (organic matter) and non-toxic, bio-based phthalate replacements for use in automotive interiors.

For more information about the Ontario BioAuto Council, please see **http://www.bioautocouncil.com**

Challenges Ahead

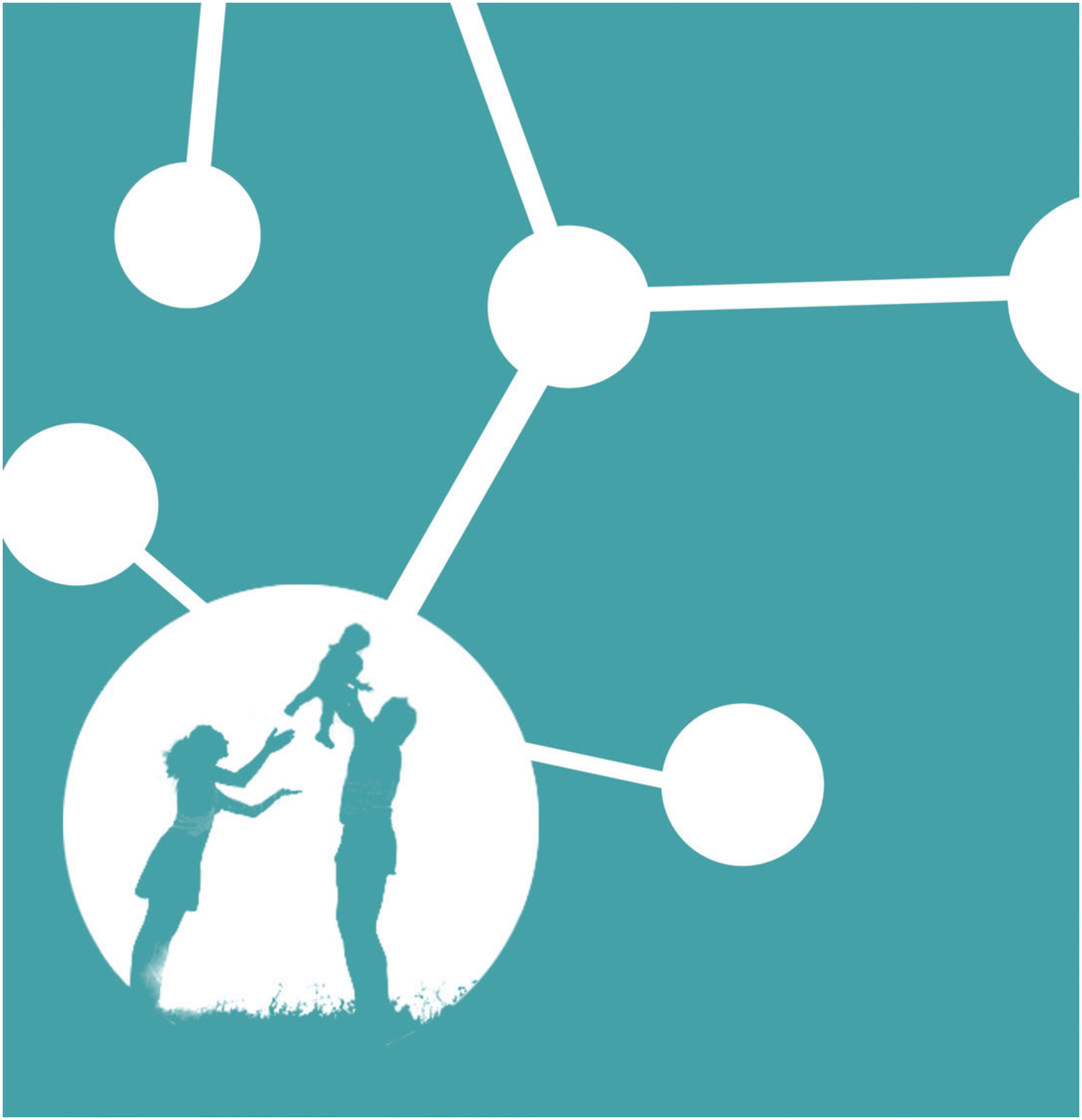
Many industries are committed to finding innovative solutions to toxic substance use. In addition to instituting change from within, these industries have voluntarily entered into environmental performance agreements with national or provincial governments to meet specified performance levels and provide accountability. Working with many regulators at all levels of government and fulfilling various reporting requirements can be a challenge for industry.

The assessment of toxic substances should include not only industrial emissions but exposure throughout the product life cycle. Efforts to minimize dispersive, non-point sources of toxic substances are most effectively addressed in the design phase. By ensuring that chemicals are used as safely as possible by industry, many of the environmental and human health effects of toxic substances can be eliminated.

In order to replace many of the toxic substances in use today, there is a need for significant research and development, and commercial scale-up. Collaborations between industry and programs that fund and support clean technology will hasten the development of viable alternatives.

Summary

Industry plays an important role in driving innovation and finding alternatives to the use, release and disposal of toxic substances. It also provides valuable information to government through regulatory reporting requirements. As individuals, we too have a responsibility. What can we do about toxic substances? Equipping ourselves with accurate information is the first step in protecting ourselves. The next chapter offers ways we can practically apply the information presented in this primer.



Chapter Seven

WHAT IS THE ROLE OF THE INDIVIDUAL?

Renovations could adversely affect your family's health: Study – Toronto Sun, March 6, 2011.

The previous chapters have covered what toxic substances are, where they come from, and what measures are currently being taken by government and industry to manage them. But perhaps some of the most important questions remain: What can I do about toxic substances? How can I apply what I have learned in this primer to my daily life to prevent exposure? When I read a headline like the one above, how do I translate it into actions that keep me and my family safe? This chapter provides strategies to help protect ourselves and our families from exposures, as well as practical applications of some of the concepts introduced in this primer.

As we have seen, toxic substances come in many shapes and forms. They can

- be released through manufacturing processes
- be integral to consumer products
- be released naturally, incidentally, intentionally or accidentally
- concentrate when moving up through the food chain

We cannot completely control our exposure to toxic substances. Some exposures arise from choices, such as the decision to smoke. Others can be the result of economic considerations, such as working in a high-risk occupation. Still others are entirely outside of our control, such as our genetic susceptibility or the nature of our childhood environment.

Children are at greater risk from the effects of toxic substances. They crawl on the floor or ground, put their fingers in their mouth, and touch and taste things without understanding that they may be harmful. Children eat, breathe and drink more per unit of body weight than adults, and thus have a higher risk of exposure. They may also be more sensitive to some toxic substances because of their stage of development.

Over the last several decades, governments have developed regulations and programs to help protect us from potential exposure to toxic substances. The large and growing number of chemical substances in use today makes it challenging to address risk comprehensively. Industry must meet the regulatory requirements for the management of toxic substances, but it also must remain competitive in the global market.

Our first line of defence as individuals should be to ensure that we have access to material that can help us make informed decisions. We should avoid harmful exposures by adopting a precautionary approach where possible. Where there is the potential for harmful effects, we should search out safer alternatives and make choices that result in the least overall risk to human health and the environment.

What You Can Do about Toxic Substances

The following sections provide practical suggestions for protecting ourselves and our families from exposure to toxic substances. The list is not exhaustive. For more information, refer to the Selected References and Useful Websites section of this primer.

To prevent exposure to toxic substances, we should

- stay informed
- use household products properly, safely and according to directions
- reduce the potential for exposures in the home
- make healthy diet and lifestyle choices
- reduce indoor and outdoor pollution
- get involved in community efforts to reduce exposures

Staying Informed

- *Keep up to date about substances currently in use, or planned for use, that are known to be toxic or of emerging concern. Assess whether the substance in question poses a significant risk based on the potential for exposure.*

Why? Becoming more aware of the unique characteristics and uses of specific substances will clarify potential risks and distinguish substances of concern.

- *Check government, civil society, and health and industry group websites and publications for the latest information about possible health effects associated with industrial processes or consumer products. For example, see Health Canada's consumer product safety website at http://www.hc-sc.gc.ca/cps-spc/index-eng.php*

Why? Information is constantly changing, and the public can draw on consumer advisories, product recalls and media reports to keep up with these changes.

Right to Know

In the context of toxic substances, the term "right to know" refers to people's right to be aware of the substances they may be exposed to in day-to-day life. It includes the right to know about the ingredients in products and the chemicals in our communities. If we know exactly what is in our products, we are in a better position to decide which products we want to use and which substances we want to avoid. In Canada, there is a movement to enact right-to-know legislation that would require ingredient and hazard labelling for household products.

Using Household Products Properly, Safely and According to Directions

• *Read the label before you buy a product and always make an informed purchase decision.*

Why? Product labels provide information on ingredients, potential hazards and claims of environmental preferability, which should be in compliance with the 2008 Competition Bureau guidelines for truth in environmental claims. With research, we can make good choices and may find that certain products are not necessary at all or that we have safer alternatives already in our home.

• *Follow the instructions and store all unused products or substances safely in their original packaging.*

Why? Product instructions specify methods of application, protective measures, ways to deal with spills or accidental releases, first aid treatment in case of exposure, and safe methods of disposal. The original packaging is designed specifically to keep the contents safely contained.

• *Keep all household products containing toxic substances out of the reach of children and teach them about the warning symbols on product labels.*

Why? It is crucial to ensure children's safety because of their increased vulnerability to some toxic substances.

Reducing the Potential for Exposure in the Home

• *Take off your shoes and any potentially contaminated clothing when you come inside. If possible, have dedicated shoe storage and launder potentially contaminated clothes separately.*

Why? Some toxic substances, including metals and pesticides, can be tracked inside on shoes and clothing. These substances can be transferred to living spaces if contaminated shoes and clothing are not removed and kept separate.

- *Maintain the air quality in your home by ensuring proper ventilation.*

Why? Toxic substances can accumulate in the home, particularly as dust. Ensuring fresh air comes into the home will cut down on exposure to toxic substances, including some phthalates, polybrominated biphenyls and short-chain chlorinated paraffins.

- *Clean up house dust with a vacuum, wet mop or damp rag.*

Why? House dust may contain residues from toxic substances. A moist means of cleaning can prevent additional exposure and avoids blowing dust into the air where it can be inhaled or settle back onto surfaces.

- *Follow safe renovation practices and ensure that only professionals handle asbestos-containing materials and dispose of related dust or residue. Seal off work areas from living spaces in order to control potential exposures to toxic substances, including lead and VOCs. Where possible, avoid renovating in winter when windows are usually not opened, making it difficult to maintain proper ventilation.*

Why? Renovations, including painting and sanding, particularly in older buildings, may disturb toxic substances that were used as ingredients in products. Lead, for example, was used in some paints during the 1950s and 60s and in older plumbing systems. Asbestos is found in some insulation and building materials and, while exposure is unlikely during normal use, fibres can be released during renovations or maintenance. Other toxic substances that may be released during renovation include VOCs (in new building materials), phthalates (in PVC plastics) and PBDEs (in fabrics or textiles).

For more information on following safe renovation practices, see **http://www.ec.gc.ca/p2/default.asp?lang=En&n=8B27B175-1**

Making Healthy Diet and Lifestyle Choices

- *Avoid tobacco products and second-hand smoke.*

Why? Tobacco products, even those that are smokeless, contain toxic substances that are known carcinogens.

For more information, see **http://www.hc-sc.gc.ca/hc-ps/tobac-tabac/fact-fait/facts-faits-eng.php**

- *Wash your hands often, especially before every meal.*

Why? Regular hand washing reduces the transmission of any substances found on our hands. This is particularly important in the case of children who crawl on the floor and then put their hand in their mouth.

• *Follow fish advisories, particularly as they apply to children and women of child-bearing age.*

Why? Fish advisories provide guidelines for distinguishing those fish that are the safest to eat from those that should be avoided, when possible, due to higher concentrations of toxic substances, such as mercury.

For Toronto Public Health's fish guide, see **www.toronto.ca/health/fishandmercury/advice_eat_fish.htm**

For more information on sport fish in Ontario, see **http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079301.pdf**

• *When possible, choose foods that are fresh, local and varied.*

Why? While these foods themselves may not be less toxic than others, they require less transport, which reduces the need for preservatives and the release of toxic substances in vehicle emissions.

• *Avoid heating food or drinks in plastic containers or plastic wrap. Where possible, use glass containers instead.*

Why? When heated at high temperatures, toxic substances such as phthalates, styrene or BPA may leach from plastic and mix with food.

Reducing Indoor and Outdoor Pollution

• *Whenever possible, bike, walk or take transit instead of driving a vehicle.*

Why? Vehicles and other fuel-burning machines release toxic substances such as benzene and other VOCs into the air. Toxic substances have also been found in elevated levels inside vehicles.

• *If you require a vehicle, choose one that is fuel-efficient and of a suitable size and power for your everyday needs. Ensure that your vehicle is well maintained (keep the engine tuned and tires properly inflated). When driving, reduce speeds, try not to idle and carpool if possible.*

Why? Exhaust from vehicles releases toxic substances into the outdoor environment. Reducing these emissions whenever possible will contribute to better air quality.

• *Do not burn garbage, particularly plastics, construction wastes, pressure-treated wood and consumer products.*

Why? Burning garbage that contains toxic substances can release these substances into the air where they can be redeposited on soil and water.

For information on burning responsibly, see **http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_076025.pdf**

- *Divert wastes that may contain toxic substances, such as batteries, electronic products or chemical cleaning products, from regular garbage disposal.*

Why? Toxic substances in landfills, including mercury, cadmium and lead found in some consumer products, can leach into the soil and groundwater if they are not properly contained or stored. Municipalities and provinces have implemented hazardous waste programs (e.g., the Orange Drop program run by Stewardship Ontario) to keep these wastes out of the environment.

Getting Involved

- *Ask questions of retailers and manufacturers. Do they meet the requirements of the current legislation related to toxic substances? Are their corporate policies clearly listed on their website or in their literature? Do they consider the life cycle of their product?*

Why? Consumer input shapes the marketplace. Letting manufacturers know that we prefer our purchases to be non-toxic and have less impact on the environment and human health will ensure the continued innovation of product design and the use of alternatives, where possible.

- *Urge businesses, organizations and government to take action on toxic substance issues.*

Why? While citizens' efforts to reduce exposure to toxic substances are important, industry and government have a responsibility to control the availability of these substances and deal with their presence in our environment. These sectors need to hear from individuals and organizations that are looking out for the best interests of the public and the environment. Advocating for proper risk assessments and appropriate preventive measures can make a difference.

TOXIC CHEMICALS THREATEN WILDLIFE, REPORT SAYS

– Toronto Star, November 3, 1987

ALARM BELLS SOUND OVER THREAT OF MERCURY CONTAMINATION

– The Chronicle Journal, Northwest Ontario, March 9, 2008

TOXIC BREW; SYDNEY RESIDENTS LIVE IN FEAR AS OFFICIALS DEBATE

– Toronto Star, May 7, 2001

BIG GREAT LAKES TROUT THE MOST TOXIC, REPORT SAYS

– CTV News, July 13, 2011

ASBESTOS BACK IN THE SPOTLIGHT

– Toronto Star, June 14, 2011

EXPOSURE TO BPA MAY BE GREATER THAN PREVIOUSLY THOUGHT

– Toronto Star, June 6, 2011

SMALL AMOUNTS OF ARSENIC FOUND IN CHICKEN FEED: FDA

– Toronto Star, June 8, 2011

RENOVATIONS COULD ADVERSELY AFFECT YOUR FAMILY'S HEALTH: STUDY

– Toronto Sun, March 6, 2011

HEALTH MINISTER PROPOSES NEW GUIDELINE ON TOXIC METAL IN KIDS' JEWELRY

– Ottawa Citizen, July 25, 2011

TOXIC EMISSIONS DOWN; DOFASCO, STELCO PRAISED FOR TAKING LEAD

– The Hamilton Spectator, July 26, 2000

CONCLUSION

The aim of this primer is to provide a better understanding of toxic substances and the basis for concern about their effects. While we have referred to specific substances in an effort to illustrate the concepts introduced, the substances themselves were not our focus. We wanted to concentrate on the issues underlying the management of toxic substances, and to give you the background information necessary to pursue further readings and research on your own.

Scientific opinion about toxic substances varies widely and is constantly changing. Not only are we discovering new substances, we are also becoming increasingly aware of the long-term effects of substances that have been in use for years. Furthermore, assessment in Canada has historically dealt with one substance at a time, making it a somewhat lengthy process; however, new approaches are being developed to streamline this process. There is no doubt that toxic substances and their management will remain a focus of continually evolving research and controversy.

It will take a concerted effort by a wide-ranging group of stakeholders to meet the challenges associated with toxic substances. While government can establish regulations, industry can drive change by improving technology and finding alternatives where possible. Civil society and environmental organizations can ensure that toxic substances remain a top priority, and individuals can make informed choices to protect themselves and their families from unnecessary exposures. Moreover, since toxic substances are not confined by geographic and political borders, our efforts must extend worldwide.

Look once again at the headlines. Do you see them differently now? Are you wondering if you are exposed to mercury in your daily life and if you could reduce that exposure? Will you view future headlines differently? The information in this primer, and the more detailed information you are encouraged to seek, will allow you to take a more proactive role in facing the challenges ahead.

GLOSSARY

The following definitions are used in this primer and apply in the context of toxic substances.

Abatement technologies – technologies using physical, chemical or biological mechanisms to capture or treat toxic substances in waste streams before they enter the environment.

Acute exposure – a brief contact with a chemical substance over a short period of time (minutes, hours, a day).

Acute toxicity – the ability of a chemical substance to inflict harm as a result of one exposure or a few brief exposures.

Best available technology (BAT)– the most effective and advanced techniques or technologies currently available for industrial use in controlling toxic discharges and emissions.

Bioaccumulation – the buildup of a chemical substance in a plant or animal that occurs when the substance is taken up and stored more quickly than it can be broken down or excreted.

Bioavailability – the degree to which a substance is absorbed in a target tissue. The absorption of some substances in humans is linked to the presence of other elements. For example, when iron, zinc and calcium are present in the diet, absorption of cadmium in humans is not significant. A deficiency of these three elements, however, may increase the amount of cadmium absorbed.

Bioconcentration – the buildup of a chemical substance in a plant or animal to a level that is higher than that of the surrounding environment. This concept is often used specifically in reference to aquatic environments and organisms.

Biodegradation – the breaking down of a material by living organisms until it is reduced to its basic ingredients or becomes a new type of material. This process varies according to the material, the temperature, and the availability of micro-organisms, water, air and light.

Biomagnification – the buildup of a chemical substance in animals ascending the food chain as animals at each level repeatedly feed on plants or animals that already contain the substance.

Biomonitoring – the measuring and analyzing of chemicals, hormone levels or other substances in biological materials (e.g., blood, urine, breath) to estimate exposure or to detect biochemical changes in the exposed subject before or during the onset of adverse health effects.

Body burden – the amount of a chemical substance that has built up in an organism (usually used in reference to humans).

Carcinogen – a substance that causes or contributes to cancer development.

Chemical substance – a material that has more or less uniform properties and is made of one or more atomic elements, such as hydrogen, oxygen, carbon, etc. A chemical substance can occur naturally (e.g., water) or be made by humans (e.g., plastic).

Chronic exposure – a continuous or repeated contact with a chemical substance over a long period of time (months, years).

Chronic toxicity – the ability of a chemical substance to inflict harm as a result of many repeated low-dose exposures over the long term.

Complex mixtures – toxic substances that occur in the environment in combination with other substances.

Contamination – the presence of a material added by human or natural activity that may, in sufficient concentrations, render the environment changed for plants and animals in its region.

Cradle to cradle – an approach to the manufacture and use of products that is modelled on the regenerative cycle of nature.

Detoxification – the process by which a toxic substance is changed to one that is less toxic or is easier for an organism to expel.

Developmental toxicant – a toxic substance that causes harm to a developing fetus or child.

Dioxins – organic compounds that are by-products of combustion processes when traces of chlorine are present. They are considered persistent, bioaccumulative and inherently toxic.

DNA (deoxyribonucleic acid) – the hereditary material in the cells of humans and almost all other organisms that contains information used to build and to maintain the organism.

Dose – the amount of a substance that an organism is exposed to over a given time.

Ecosystem – system formed by the interaction of a community of organisms and their physical environment.

Endocrine disruptor – a substance that can affect the functioning of the endocrine system. Endocrine disruptors have been associated with developmental, reproductive and other health problems in wildlife and laboratory animals. There is concern that they could affect humans in similar ways.

Endocrine system – the communication system of glands, hormones and cellular receptors that control the body's internal functions.

End-of-pipe control – control of the release of a toxic substance to the environment by treatment at the last stage of a process, as opposed to revising the process to avoid the use or creation of the toxic substance.

Epidemiology – the study of the frequency, distribution and determining factors of disease risk in human populations, and the determination of the specific causes of localized outbreaks of diseases.

Food chain – a sequence of organisms arranged in the order that they consume each other. Each link of the chain represents a species or group of species (e.g., grass > grasshopper > toad > snake > hawk). Due to their varied diet, most animals are part of more than one food chain.

Food web – the interconnected food chains that represent the varied diet typically consumed by animals within an ecosystem.

Gene – a part of each cell in a plant or animal that contains a unique sequence of DNA and is involved in determining growth, development and health.

Grandfathering – granting an existing operation or situation an exemption from a new regulation.

Grasshopper effect – a process by which certain chemical substances, including some toxic substances, are transported from warmer to colder climates. Substances evaporate from water or soil into warm air where they are transported by wind currents and eventually redeposited on the water or soil as temperatures cool. This cycle of evaporation, airborne movement and deposition can repeat multiple times, mimicking a "hopping" movement, hence the term "grasshopper."

Green chemistry – designing chemical products and processes so as to reduce or eliminate the use or generation of hazardous substances.

Groundwater – the supply of fresh water found beneath the Earth's surface.

Heavy metals – a general term used to describe more than a dozen metallic elements. Some, such as zinc, copper and iron, although harmful at high concentrations, are essential parts of our diets at trace levels. Others, like lead and mercury, have no known health benefits and can have harmful effects on human health and the environment even at very low concentrations.

Immunosuppression – a condition in which the functioning of the immune system of an organism is reduced.

Immunotoxicant – a substance that reduces the ability of an organism to protect itself against disease.

Incidental release – a release of a toxic substance that occurs in a natural substance as a result of human activity (e.g., an incidental release of a toxic substance found naturally in the Earth's crust could result from smelting and manufacturing operations).

Indicator species – an animal species selected for study because it is specific to a certain region, is near the top of a food web, and is sensitive to pollution or human interference. A change in the health or number of the species can indicate the presence of a toxic substance or other environmental issues.

Industrial ecology – the study of the flow of materials and energy through industrial systems, intended to provide principles for interaction with natural ecosystems and sustainability. Strategies include using waste material or energy from one industry as part of the material or energy supply of another industry, thus reducing raw material use and pollution.

Intentional release – a release of a toxic substance arising from the manufacture, use or disposal of a product that deliberately contains the substance or that is the result of a process that deliberately uses the substance.

LD_{50} – a general measure of the acute toxicity of a substance. LD_{50} is an abbreviation for "Lethal Dose, 50 per cent," which is the dose at which 50 per cent of a tested population dies when exposed to a toxic substance for a specified duration. The smaller the LD_{50} number, the more lethal the substance.

Life cycle – the normal stages of existence of a substance or product from beginning to end.

Mutagenic – a chemical substance that can cause changes in the DNA.

Neurotoxicant – a toxic substance that affects the brain or nervous system.

Non-point source – a source of releases of the same type that are too numerous to attribute to a point source.

Non-threshold substance – a substance that poses a risk of harm at any dose.

Particulate matter (PM) – microscopic liquid droplets and particles of soot, dust, metals or pollens that are suspended in air for any length of time. PM comes from human sources, such as burning of fuels, industrial processes and construction, as well as natural sources, such as fog, dust and forest fires. PM is one of the main components of smog.

Persistent – in reference to a substance, remaining in the environment for long periods of time, thus increasing opportunities for exposure.

Phthalates – a class of chemical substances commonly used to soften polyvinyl chloride (PVC) plastic in medical equipment and consumer products, including children's toys, flooring, packaging, paints and lubricants. Some phthalates have been linked to reproductive and developmental toxicity, and liver and kidney effects in rodents. Restrictions under the *Canada Consumer Product Safety Act* (CCPSA) have been applied to some phthalates.

Point source – an identifiable, confined and separate source of emissions (e.g., an industrial chimney).

Reproductive toxicant – a toxic substance that has an adverse effect on male or female sexual functioning or reproductive ability.

Risk – a function of the hazardous properties of a chemical substance and the means of exposure to those properties.

Risk assessment – a scientific evaluation of a chemical substance to determine its potential harm to human health and/or the environment, and the means of exposure. It allows for the identification of control measures to avoid or prevent potential harm.

Risk management – a decision-making and management process to identify, evaluate, select and implement actions to reduce risks to human health and the environment. Risk management includes pollution prevention and the control, reduction or elimination of toxic substances.

Route of exposure – the pathway by which a person, an animal or the environment comes into contact with a toxic substance. Typical routes of exposure for humans are absorption through the skin, breathing and swallowing.

Substance of emerging concern – a substance that occurs widely in the environment, that has been identified as a potential human health or environmental risk, and that has not been assessed to determine its risk due to inadequate data.

Threshold substance – a substance that has a specific dose below which no harmful effect is expected to occur. The level of this dose may vary among individuals and species.

Timing (of exposure) – the stage of life (e.g., fetus, child, adult) when an organism's exposure to a toxic substance takes place.

Toxic substance – a chemical substance that is considered a risk for serious harm to human health or the environment (for the purposes of this primer, we have confined our discussion to the toxic substances identified under prevailing law).

Transport and fate – the movement and alteration of a chemical substance in the environment. For example, mercury, when released into the atmosphere, can travel long distances on wind currents, settle in bodies of water, convert into methylmercury and bioaccumulate as it moves up the food web.

Uptake – the drawing up or absorption of a chemical substance into an organism.

Virtual elimination – for the purposes of regulation, reducing the quantity or concentration of a substance in a release to below the lowest level that can be accurately measured using sensitive but routine sampling and analytical methods.

Volatile organic compound (VOC) – any of a group of chemical substances containing carbon and hydrogen that evaporate quickly at room temperature. VOCs are linked to toxic effects and the formation of smog.

Water column – an area of a lake, river or ocean extending from the water surface to the bottom sediments. This representation is typically used when studying the variations in chemistry and biology that occur according to depth.

SELECTED REFERENCES AND USEFUL WEBSITES

Government and International Programs

Government of Canada

ABORIGINAL AFFAIRS AND NORTHERN DEVELOPMENT CANADA

Publications – Northern Contaminants Program. http://www.ainc-inac.gc.ca/ai/scr/nt/ntr/pubs/index-eng.asp#Contaminants

ENVIRONMENT CANADA

Canadian Environmental Protection Act, 1999. http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=126220C5-1

The Chemicals Management Plan (with Health Canada). http://www.chemicalsubstanceschimiques.gc.ca/index-eng.php

Fact Sheet. Pollution and Waste. www.ec.gc.ca/subsnouvelles-newsubs/default.asp?lang=En&n=C9ECF2A3-1

Great Lakes Fact Sheets. http://www.ec.gc.ca/tho-wlo/default.asp?lang=En&n=FB7123A4-1

Guidance Document. New Substances Notification Regulations. www.ec.gc.ca/subsnouvelles-newsubs/default.asp?lang=En&n=ED6ABB02-1

Issues in Our Communities. Renovation and Maintenance. http://www.ec.gc.ca/p2/default.asp?lang=En&n=8B27B175-1

Management of Toxic Substances. http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=97324D33-1

National Pollutant Release Inventory. www.ec.gc.ca/inrp-npri/

Pollution Prevention for Citizens and Society. http://www.ec.gc.ca/p2/default.asp?lang=En&n=7B516690-1

Toxic Substances List – Schedule 1. http://www.ec.gc.ca/lcpe-cepa/default.asp?lang=En&n=0DA2924D-1&wsdoc=4ABEFFC8-5BEC-B57A-F4BF-11069545E434

Toxic Substances Management Policy. http://www.ec.gc.ca/toxiques-toxics/default.asp?lang=En&n=2A55771E-1

ENVIRONMENTAL REGISTRY

Certificates of Approval with Environmental Compliance Approvals. http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MTEyNDc4&statusId=MTY4NzEx

HEALTH CANADA

Assessing and Managing the Risks of Existing Substances under the Renewed *Canadian Environmental Protection Act, 1999* (CEPA 1999). http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/environ/assess-eval-eng.php

Breastfeeding and Infant Nutrition. http://www.phac-aspc.gc.ca/hp-ps/dca-dea/stages-etapes/childhood-enfance_0-2/nutrition/index-eng.php

Canada Consumer Product Safety Act (CCPSA). http://www.hc-sc.gc.ca/cps-spc/legislation/acts-lois/ccpsa-lcspc/index-eng.php

Chemical Substances. http://www.chemicalsubstanceschimiques.gc.ca/index-eng.php

Consumer Product Safety. http://www.hc-sc.gc.ca/cps-spc/index-eng.php

Environmental and Workplace Health. http://www.hc-sc.gc.ca/ewh-semt/index-eng.php

Food and Drug Act and *Regulations*. http://www.hc-sc.gc.ca/fn-an/legislation/acts-lois/act-loi_reg-eng.php

Food and Nutrition. http://www.hc-sc.gc.ca/fn-an/index-eng.php

Glossary. http://www.chemicalsubstanceschimiques.gc.ca/glossary-glossaire-eng.php#i

Hazardous Products Act. http://laws.justice.gc.ca/en/H-3/index.html

Healthy Canadians. http://www.healthycanadians.gc.ca/index-eng.php

It's Your Health Fact Sheets. http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/index-eng.php

Pest Control Products Act. http://laws-lois.justice.gc.ca/eng/acts/p-9.01

Tobacco Scientific Facts. http://www.hc-sc.gc.ca/hc-ps/tobac-tabac/fact-fait/facts-faits-eng.php

Canadian Council of Ministers of the Environment

Comprehensive Air Management System (CAMS) Steering Committee. *Comprehensive Air Management System. A Proposed Framework to Improve Air Quality Management.* http://www.ccme.ca/assets/pdf/cams_proposed_framework_e.pdf

Homepage. http://www.ccme.ca/

Province of Ontario

MINISTRY OF THE ENVIRONMENT

Burning Responsibly. http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_076025.pdf

Drinking Water Ontario. http://www.ontario.ca/drinkingwater

Environmental Protection Act, Regulation 347, General – Waste Management. http://www.e-laws.gov.on.ca/html/regs/english/elaws_regs_900347_e.htm

Guide to Eating Ontario Sport Fish (2011-2012). http://www.ene.gov.on.ca/environment/en/mapping/sportfish/index.htm

Toxics Reduction Act. http://www.ene.gov.on.ca/environment/en/legislation/toxics_reduction_act/index.htm

Toxic Substances. http://www.ene.gov.on.ca/environment/en/category/toxic_substances/index.htm

City of Toronto

ChemTRAC Program. http://www.toronto.ca/health/chemtrac/index.htm

Guide to Eating Fish for Women, Children and Families. http://www.toronto.ca/health/fishandmercury/pdf/guide_eat_fish.pdf

United States Environmental Protection Agency

Green Chemistry. http://www.epa.gov/greenchemistry/

International Programs

The Arctic Monitoring and Assessment Programme (AMAP). http://www.amap.no/

Stockholm Convention on Persistent Organic Pollutants. http://chm.pops.int/

United Nations Environment Programme (UNEP). Harmful substances and hazardous waste. http://www.unep.org/hazardoussubstances/

United Nations Environment Programme (UNEP). Mercury. http://www.unep.org/hazardoussubstances/Mercury/tabid/434/language/en-US/Default.aspx

Industry and Industry Groups

Chemistry Industry Association of Canada. Responsible Care®. www.canadianchemistry.ca/ResponsibleCareHome.aspx

Competition Bureau of Canada and Canadian Standards Association. PLUS 14021 *Environmental claims: A guide for industry and advertisers.* http://www.csagroup.org/%5Crepository%5Cca%5CPLUS_14021-08EN.pdf

Green Centre Canada. http://www.greencentrecanada.com

GTAA Partners in Project Green – A Pearson Eco-Business Zone. http://www.partnersinprojectgreen.com/

Ontario BioAuto Council. http://www.bioautocouncil.com

Stewardship Ontario. Orange Drop recycling program. http://www.makethedrop.ca/

Other

Breast Cancer Fund. 10 Canned Foods to Avoid Wallet Card. www.breastcancerfund.org/clear-science/innovative-research/food-packaging-study/wallet-card.html

Canadian Partnership for Children's Health & Environment (CPCHE). CPCHE Educational Materials. http://www.healthyenvironmentforkids.ca/collections/cpches-educational-materials

The Consortium for Research and Education on Emerging Contaminants (CREEC). http://www.creec.net/

The Endocrine Society. http://www.endo-society.org/

Garner, A. and Keoleian, G. (1995). *Industrial Ecology: An Introduction.* http://www.umich.edu/~nppcpub/resources/compendia/INDEpdfs/INDEintro.pdf

The Lung Association. www.lung.ca

Massey, R. I., Hutchins, J. G., Becker, M., & Tickner, J. (2008). *Toxic Substances in Articles: The Need for Information.* Copenhagen: TemaNord.

McDonough, W. & Braungart, M. The Cradle-to-Cradle Alternative. http://www.mcdonough.com/writings/cradle_to_cradle-alt.htm

Pollution Probe. (2001). *Applying the Precautionary Principle to Standard Setting for Toxic Substances in Canada*. http://www.pollutionprobe.org/old_files/Reports/precautionary.pdf

Pollution Probe Primer Series. http://www.pollutionprobe.org/publications/primers.html

- *Primer on Automobile Fuel Efficiency and Emissions*
- *Primer on Volatile Organic Compounds*
- *Child Health and the Environment – A Primer*
- *The Source Water Protection Primer*
- *Mercury in the Environment: A Primer*
- *Drinking Water Primer*
- *The Smog Primer*

Region of Peel. Eat Fish for Health. http://www.peelregion.ca/health/eatfish

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