

DIOXINS & FURANS



The Canadian Perspective

CCME

Canadian Council
of Ministers
of the Environment

Le Conseil canadien
des ministres
de l'environnement

This publication has been prepared by the Canadian Council of Ministers of the Environment (CCME) to present the facts from a Canadian perspective on chlorinated dioxins and furans. Specifically, it includes information about the sources and effects of dioxins and furans as well as the government actions that are underway to control these chemicals.

What are Dioxins and Furans ?

Dioxins is a simplified term for the family of 75 related chemical compounds known as polychlorinated dibenzo-p-dioxins. A similar family called polychlorinated dibenzofurans contains 135 related chemical compounds. These chemicals are referred to as "furans".

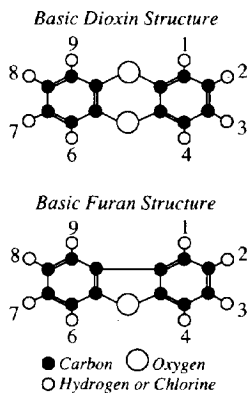


Figure 1. The basic chemical structures of dioxins and furans. Chlorine atoms can be attached at any of the numbered positions.

These two families of compounds have similar chemical structures (see Figure 1), biological effects, and toxic responses and will be dealt with as a group. Both families can have between one and eight chlorine atoms attached to the parent molecule. Mono, di, tri, tetra, penta, hexa, hepta and octa are prefixes denoting the attachment of one to eight chlorine atoms, respectively.

Are all Dioxins and Furans the same?

No they are not. The most toxic dioxin is 2,3,7,8-tetrachlorodibenzo-para-dioxin (2,3,7,8-TCDD); the chemical structure of this compound is shown in Figure 2.

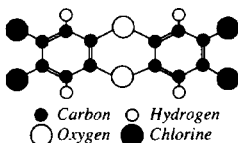


Figure 2: 2,3,7,8-tetrachlorodibenzo-p-dioxin

Most people assume that 2,3,7,8-TCDD is the form of dioxin present when the word "dioxin" is commonly used. This is usually not the case and, in fact, 2,3,7,8-TCDD normally makes up only a small percentage of the dioxin and furan mixtures found in Canada. Scientists have not yet studied other dioxins and furans as intensively as 2,3,7,8-TCDD; however, it is known that some of them are toxic, although less so than 2,3,7,8-TCDD.

How do other Dioxins and Furans compare to 2,3,7,8-TCDD?

Only 17 of the 210 dioxins and furans have chlorine atoms attached at the same lateral 2,3,7,8 positions as 2,3,7,8-TCDD. These compounds contribute most to the toxicity of complex mixtures of dioxins and furans. International

Toxicity Equivalency Factors (I-TEFs) are assigned to the other 16 dioxins and furans based on how toxic they are in comparison to 2,3,7,8-TCDD. Thus, 2,3,7,8-TCDD has been assigned an I-TEF of 1.0. The other 2,3,7,8 substituted compounds are one-half to one-thousandth as toxic as 2,3,7,8-TCDD (Table 1). The non 2,3,7,8-substituted dioxins and furans have much lower toxicities in comparison and are assigned an I-TEF of zero. The I-TEF is multiplied by the concentration of each 2,3,7,8-substituted dioxin or furan and the resulting concentrations are summed as total 2,3,7,8-TCDD TEQs (toxic equivalents). Environment Canada and a number of provinces use the I-TEF method as a means of comparing the relative toxicity of complex mixtures of dioxins and furans. For example, if a soil sample contains 10 pg/g 2,3,7,8-TCDD and 20 pg/g 2,3,7,8 TCDF, the total 2,3,7,8-TCDD TEQs = (10 pg/g x 1.0) + (20 pg/g x 0.1) = 12 pg/g 2,3,7,8-TCDD TEQs.

Table 1. International Toxicity Equivalency Factors (I-TEFs) (NATO 1988)

COMPOUND*	I-TEF
Dioxins	
2,3,7,8-TCDD	1.0
1,2,3,7,8-PeCDD.....	0.5
1,2,3,4,7,8-HxCDD.....	0.1
1,2,3,7,8,9-HxCDD.....	0.1
1,2,3,6,7,8-HxCDD.....	0.1
1,2,3,4,6,7,8-HpCDD.....	0.01
OCDD	0.001
Furans	
2,3,7,8-TCDF.....	0.1
2,3,4,7,8-PeCDF	0.5
1,2,3,7,8-PeCDF	0.05
1,2,3,4,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF.....	0.001

*TCDD_iF, PeCDD_iF, HxCDD_iF, HpCDD_iF, OCDD_iF indicate tetra to octa chlorinated dioxins and furans, respectively.

Dioxins and furans appear in very minute levels throughout the environment. Studies indicate that dioxins and furans, especially 2,3,7,8-TCDD, are mainly the result of human activity, although some research has implicated forest fires as natural sources. Dioxins and furans are not intentionally produced. They are the byproducts created during the manufacture of other chemicals such as some pesticides (e.g. chlorophenols and 2,4,5-T), or from the use of chlorine in pulp bleaching, or in the incomplete combustion of material containing chlorine atoms and organic compounds.

In the past, the uncontrolled disposal of polychlorinated biphenyls (PCBs) led to the dispersal of significant amounts of furans into the environment. Today most PCBs are stored in secure containment facilities and are only a source of furans through accidental leakages or fires.

Transboundary sources are important contributors of dioxins and furans to the lower Great Lakes. These include leakage from the large waste disposal sites in the United States bordering the Niagara River, and airborne dioxins and furans from incinerators and other combustion and chemical sources. The extent of these sources has not been fully quantified.

In 1985, Environment Canada estimated the dioxin and furan emissions in Canada. Since that time there have been major improvements in analytical chemistry techniques and control technologies for dioxins and furans. Due to these changes the use of the 1985 emission estimates may no longer be reasonable. In 1989, Environment Canada estimated the dioxin and furan emissions from municipal solid waste incinerators to be 50g 2,3,7,8-TCDD TEQs and discharges from bleached kraft pulp mill effluents in 1988/89 to be 280g 2,3,7,8-TCDD TEQs. In 1991, dioxin and furan emissions from bleached kraft pulp mill effluent were estimated to be reduced to 20g 2,3,7,8-TCDD TEQs and this is projected to decrease to less than 5g 2,3,7,8-TCDD TEQs by 1994.

Data on humans show that we have all been exposed to dioxins and furans. The current level of exposure of Canadians is mainly to dioxins and furans of low toxicity compared with 2,3,7,8-TCDD. However, no increases in this exposure should be allowed.

Assessing where the greatest exposure comes from and how to reduce it is a difficult and complex task. Exposure could be from breathing air, drinking water, eating food or coming into contact with contaminated consumer products, soil or dust.

A recent Canada-Ontario study has estimated the average total exposure of Canadian adults and children to dioxins and furans from all possible pathways. These estimates are based on average Canadian intakes of air, water, soil and food with representative concentrations of dioxins and furans. Between 94 and 96 percent of the intake by non-smoking adults is estimated to be from food, with the remainder evenly split between air and all other routes.

An estimated average lifetime daily intake of 2.0 to 4.2 picogram 2,3,7,8-TCDD TEQs per kilogram of body weight per day can be derived from this study. This is based on assumptions that are likely to overestimate exposure in the interest of protecting human health. A picogram is one-trillionth of a gram.

Over the past several years, very sensitive and accurate techniques have been developed to detect baseline environmental concentrations of dioxins and furans as low as several parts per trillion or even parts per quadrillion. At these very minute levels, dioxins and furans have been found in many soil, air, water, wildlife, food and body fat samples. Higher levels (in the parts per billion range) have been measured at disposal sites and in sediment samples obtained near property contaminated with industrial wastes.

To understand parts per trillion, just imagine one grain of salt in an Olympic-sized pool. For parts per quadrillion, think of the area of a two-dollar bill compared to the area of Canada.

Are Dioxins and Furans hazardous to our environment?

A growing body of evidence indicates that dioxins and furans or related compounds are already adversely affecting wildlife.

Dioxins and furans have certain properties that can increase their potential hazard to both the environment and ourselves. These properties include:

Persistence

Many dioxins and furans are resistant to biological and chemical breakdown and remain in the environment for years.

Bioaccumulation

When certain dioxins and furans are taken up by living organisms, they're not readily excreted. This means they can accumulate in organisms, with the highest concentration of dioxins and furans found in fatty tissues. It also means that dioxins and furans can become concentrated up the food chain. For example, microscopic aquatic plants and animals living where water is contaminated by certain industrial wastes will absorb dioxins and furans in their tissues. These dioxins and furans will then be accumulated in the tissues of fish that eat these contaminated smaller plants and animals. In turn fish-eating birds may eat the contaminated fish. Humans can also be exposed by eating contaminated fish or birds.

A diet of the more highly contaminated fish from the Great Lakes could result in a cumulative dose exceeding the no-effect levels for sensitive wildlife species such as mink. Reproductive failure and birth defects in fish-eating birds on the Great Lakes and on the West Coast of Canada have been observed. They correlate strongly with dioxin and furan levels in eggs and adult bird tissues. Studies of fish-eating, colonially-nesting birds attribute low reproductive success to two major factors: chemicals in eggs that are toxic to embryos, and abnormal behaviour caused by pollutants, resulting in poor nest incubation and care of offspring. Such effects of reproduction and development are characteristic of exposure to dioxins and some of the other organochlorine contaminants that may co-occur with dioxins and furans.

Are Dioxins and Furans hazardous to our health?

While laboratory experiments on animals and studies of human health effects have tried to determine the full effects of dioxins and furans on our health, only results from animal testing have been definitive. So far, scientists have determined the following:

Effects on laboratory animals

Laboratory animals exposed to 2,3,7,8-TCDD experienced a number of adverse health effects. These include:

- loss of weight
- skin disorders
- effects on their immune system
- impaired liver function
- altered blood function
- impaired reproduction including birth defects
- increased incidence of tumors
- increased production of certain enzymes that break down foreign chemicals in the body.

Some of these effects can be caused by several other dioxins and furans depending on their toxicity relative to 2,3,7,8-TCDD (see Table 1). Rarely, however, will a single animal species show the complete spectrum of toxic and biological effects. Furthermore, laboratory animals show a wide range of sensitivity, i.e., guinea pigs are over five thousand times more sensitive than hamsters.

Effects on humans

While we know the range of concentrations of 2,3,7,8-TCDD that cause adverse health effects in laboratory animals, it's not easy to extrapolate this knowledge to humans.

We know that humans have been accidentally exposed to high levels of dioxins and furans in certain occupations, such as pesticide manufacturing and pesticide use such as wood preservation. Some people in the general population have been accidentally exposed to dioxins or furans following industrial accidents or improper waste disposal. So far, we only have conclusive evidence of one human health effect related to dioxin or furan exposure - a temporary, non-life threatening skin condition called chloracne.

The effects of chronic human exposure to dioxins and furans are still being investigated. People are usually exposed to dioxins and furans in chemical mixtures containing various other toxic substances. This makes it difficult to conclusively link evidence of adverse effects in humans specifically to dioxins or furans. Three recent studies of workers exposed to 2,3,7,8-TCDD have found an association between this exposure and the development of various types of cancer. However, the sum of current scientific evidence does not indicate any link between current, everyday human exposure to dioxin or furan containing chemicals and the development of cancer. Ongoing research on the effects of dioxins and furans on the primate and human immune system, fetus and the newborn may give new insight into acceptable levels of dioxin and furan exposure.

The Department of National Health and Welfare has derived a Tolerable Daily Intake (TDI) of 10 pg/kg/day 2,3,7,8-TCDD TEQs for the average lifetime human exposure to dioxins and furans. The estimated Canadian lifetime intake is one-half to one-fifth of this TDI. Other jurisdictions have developed acceptable human dioxin and furan intakes that are higher and lower than this value. This indicates that higher levels in our environment should not be tolerated.

What are Governments doing?

Federal, provincial and territorial governments have initiated major programs to reduce environmental contamination and human exposure to dioxins and furans. They are working together to harmonize management strategies for controlling these toxic substances. The Canadian approach is as follows:

- Dioxins and furans were identified to be toxic substances under the Canadian Environmental Protection Act.
- Federal regulations were instituted to control dioxins and furans in effluents from pulp and paper mills. These regulations prohibit the use of certain products which contain dioxin and furan precursors and require the imple-

mentation of process changes to prevent the formation of dioxins and furans in the pulp bleaching process. As a result, these regulations will eliminate the formation of dioxins in the course of pulp manufacturing.

- Codes of practice have been developed to prevent environmental contamination by wood treatment industries.
- The Canadian Council of Ministers of the Environment (CCME) issued operating and emission guidelines addressing dioxins and furans in municipal solid waste incinerator emissions.
- Development of criteria for dioxins and furans in food, water, soil, consumer products, sediments and contaminated sites was initiated.
- Extensive monitoring of dioxins and furans in fish in the vicinity of bleached chemical pulp mills is ongoing; closures or advisories to limit consumption of dioxin contaminated fish are announced where necessary to protect human health.
- Negotiations were initiated with the United States to clean-up hazardous wastes sites along the USA/Canada border.
- Canada's federal, provincial and territorial governments are conducting or encouraging dioxin and furan research to further our understanding of their formation, environmental behaviour and effects, and to better estimate human exposure to dioxins and furans.
- Federal and provincial agencies have established in-house dioxin and furan laboratories and promoted the development of private dioxin and furan laboratories. This has allowed a large number of samples to be analyzed at parts per trillion (pg/g) or parts per quadrillion (pg/kg) levels and resulted in a decrease in cost from \$3,000 per sample to approximately \$1000 per sample.

Yes we are. Levels of dioxins and furans in sensitive environmental indicators such as Great Lakes fish and herring gulls (fish-eating birds) are declining. As well, the levels of dioxins have decreased markedly in Great Blue Heron eggs from a colony located adjacent to a pulp mill on British Columbia's Georgia Strait.

Much of this improvement is due to actions taken by government to restrict or eliminate sources of dioxins and furans. For example, the federal government has deregistered the sale and use of pesticides containing 2,3,7,8-TCDD and regulated the content of other dioxins in pesticides remaining on the market. Monitoring programs indicate that no 2,3,7,8-TCDD is found in current pesticide products. The use of polychlorinated biphenyls (PCBs) in new electrical equipment has been banned and its use in existing equipment is being phased out.

Canadian governments have also established codes of practice for the wood protection and preservation industries to reduce environmental contamination. The use of chlorophenol contaminated wood chips by the pulp industry has been banned. Some provinces have developed guidelines and regulations to reduce exposure to dioxins and furans in air, water, soil and solid wastes. Other provincial initiatives include assessment and cleanup of sites contaminated with dioxins and furans, and the imposition of more stringent pollution controls on new incinerators and implementation of strategies to abate industrial and municipal effluents. New federal, provincial and territorial initiatives are expected to reduce and eventually eliminate emissions of dioxins and furans from pulp and paper mills and reduce releases from other sources.

Dioxins and furans occur throughout the environment and minute amounts have been detected in the fatty tissues of Canadians. They have sometimes produced transient adverse effects in humans following occupational and accidental exposure to high levels of contamination.

There are uncertainties related to measuring the real dose received by humans and difficulties in assessing toxic effects in humans other than the skin disorder chloracne. This prevents a firm conclusion being drawn on the relative sensitivity of humans to the toxic effects of these compounds. Government actions to date in banning and regulating chemical products, combustion sources, and other processes contaminated with dioxins and furans have resulted in the reduced release of these contaminants to the Canadian environment. However, much remains to be done and we need to continue our efforts to further reduce the release of these chemicals to our environment.

Below is a partial list of available international, federal and provincial publications on dioxins and furans. For further information you may wish to contact your library or your nearest provincial or federal Environment offices.

Environment Canada and Health and Welfare Canada. 1990 - Priority substances list assessment report no. 1: polychlorinated dibenzodioxins and polychlorinated dibenzofurans. 56 pages.

Environment Canada. 1985 - Polychlorinated Dibenzop-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs): Sources and Releases. Report - EPS 5/HA/2. 47 pages.

Health and Welfare Canada and Environment Canada. 1983 - Report of the Joint Health and Welfare Canada/Environment Canada Expert Advisory Committee on Dioxins. 57 pages.

Ministère de l'Environnement du Québec. 1985 - La problématique des dioxines et des furannes au Québec. Envirodoq 850797, 73 pages.

National Research Council of Canada. 1985 - Polychlorinated Dibenzofurans: Criteria for their Effects on Man and his Environment. NRCC Publication No. 22846, 243 pages.

National Research Council of Canada. 1981a - Polychlorinated Dibenzop-dioxins: Criteria for their Effects on Man and his Environment. NRCC Publication No. 18574, 251 pages.

North Atlantic Treaty Organization (NATO). Committee on the Challenges of Modern Society. 1988 - Pilot Study in international information exchange on dioxins and related compounds. International toxicity equivalency factor (I-TEF) method of risk assessment, report No. 176.

Ontario Ministry of the Environment. 1985 - Scientific Criteria Document for Standard Development. No. 84-4. Polychlorinated dibenzo-p-dioxins (PCDDs) and Polychlorinated dibenzofurans (PCDFs). September 1985. 536 pages.

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The Canadian Council of Ministers of the Environment (CCME) is the major intergovernmental forum in Canada for discussion and joint action on environmental issues of national, international and global concern. The 13 member governments work as partners in developing nationally consistent environmental standards, practices and legislation.

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ISBN 0-919074-13-8
CCME-EPC-60E