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A Reference Manual of Chemical Contaminants in Ontario Sport Fish

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A REFERENCE MANUAL
OF CHEMICAL CONTAMINANTS
IN ONTARIO SPORT FISH

Report Prepared by:
C. Cox and J. Ralston
Water Resources Branch
Ontario Ministry of the Environment

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1.0 Introduction

1.1 Purpose of the Manual

This manual is designed to supplement the information provided in the "Guide to Eating Ontario Sport Fish" with regard to contaminants in Ontario sport fish. It includes information on the occurrence, uses, accumulation and trends through time of the various contaminants tested in Ontario sport fish. The possible effects of the contaminants on human health and the consumption guidelines for contaminants tested by the Sport Fish Contaminant Monitoring Program are also included.

1.2 Sport Fish Contaminant Monitoring Program

The Ontario Government began monitoring contaminant levels in sport fish in the 1960's when concerns were first raised about the effects of substances such as DDT on aquatic life.

In the late 1960's, the Province of Ontario became aware of mercury contamination due to chlor-alkali (chlorine production) plant discharges. In the early 1970's, these sources were either eliminated or severely restricted, and intensive fish monitoring programs were initiated at the affected sites.

During the 1970's, studies of contaminants in fish expanded to include such substances as PCBs, mirex, organochlorine pesticides and other organic chemicals.

In 1976, the Province of Ontario started the Sport Fish Contaminant Monitoring Program, to test as many angling areas as possible and assess all statistically reliable data on contaminants in fish. The program is a coordinated undertaking of the Ontario Ministries of Environment and Natural

A rainbow trout from the Niagara River.

Resources. Advice on human health protection is provided by medical specialists in the Ministry of Labour and Health and Welfare Canada.

The selection of locations for the testing of sport fish is an ongoing process, and a location may be selected for one or more of the following reasons:

- it is a popular angling area.
- there is a known or suspected source of pollution nearby.
- it is a major source of food for local inhabitants (usually lakes in the vicinity of Indian reserves).
- it is being opened for recreational development.
- it is part of a monitoring program for long-term studies of contaminants in fish.

Fish are collected by the staff of the Ministry of Natural Resources using various netting methods. Whenever possible, 20 fish of each species to be tested are included, with lengths and weights representative of the size range of that species in the location being tested.

The selection of the appropriate species for testing at a particular location depends upon which contaminants are to be analyzed for in fish from that location. Not all species accumulate a particular contaminant at the same rate, therefore one species of fish of a certain size may contain a much lower contaminant concentration than another species of the same size. This is because different fish feed on different things, prefer different habitats, grow at different rates and are physiologically different.

Therefore, when testing fish for mercury in a specific area, the practice is initially to select those species which are top predators, as they will indicate the highest mercury levels likely to be found.

If low levels of mercury are found in predators, the testing of other species may not be necessary.

In testing for organic contaminants such as PCBs and mirex, species with high lipid (fat) levels, such as salmon, lake trout and smelt are selected since organic chemicals usually tend to accumulate in fatty tissue.

Again, if these species do not contain excessive levels of organic contaminants, then less fatty species from the same location usually do not have to be tested.

Once the appropriate species have been collected, skinless, boneless dorsal fillets are prepared. These samples not only provide the most consistent test results, but also represent the best edible portion of most sport fish.

The samples are frozen and shipped to the Ministry of the Environment laboratories in Toronto or Thunder Bay for contaminant analysis.

At the Ministry of the Environment laboratories, the fish samples are ground and prepared for analysis. All fish are analyzed for mercury, which is a naturally occurring element found in varying levels in all fish sampled throughout the province.

At most inland locations, it is usually only necessary to analyze the samples for mercury, unless a human source of pollution is suspected. For areas possibly affected by human sources of pollution

(mainly Great Lakes locations), tests are done for a number of additional contaminants, including PCBs, mirex and DDT.

The results of the analyses are computerized and sent to the Sport Fish Contaminant Monitoring Program for interpretation, and consumption advisories for Ontario anglers are developed for

various sizes of each species tested. The advice is based on federal Health and Welfare Canada guidelines for commercially marketed fish. These guidelines are incorporated into the annually updated "Guide to Eating Ontario Sport Fish", which gives size-specific consumption advice on sampled species from over 1600 locations in Ontario.

Fish samples are ground and prepared for analysis at the Ministry of the Environment laboratories.

2.0 Contaminants

There are many naturally occurring substances, such as mercury, which pose no hazard to the environment or to human health at levels normally found in air, water, and food. A number of synthetic organic substances, such as PCBs, mirex and dioxin, may also be found in the environment. When the level of these substances exceeds Health and Welfare Canada guidelines, then these substances can be called contaminants of concern.

The Ontario government is concerned about the accumulation of naturally occurring and synthetic contaminants in Ontario sport fish.

This chapter will describe some of the metals, pesticides and industrial organic substances that have been found or have the potential to be found in Ontario sport fish.

A summary of available information is provided on the sources and uses of the substances, their pathways to fish, and their effects on human health.

Readers interested in more comprehensive information in any one area are encouraged to seek out more detailed scientific reports. A bibliography at the end of this report may help in that regard.

Inorganic Substances

2.1 Mercury

a) Occurrence

Mercury is a naturally occurring metallic element, which is found in very low levels in air and water, and also found in rocks, soil, and plant and animal matter.

It is the only metal which is liquid at room temperature.

b) Uses

Mercury has been used in such processes as:

- chlorine production (chloralkali plants)
- manufacturing of electrical equipment (batteries and switches)
- mining (gold and silver)
- agriculture (seed dressing and root dip)
- pulp and paper (slimicides)
- manufacturing of scientific instruments (thermometers, barometers)
- amalgams in dental fillings
- mildew proofing in paints and coatings
- fungicide on golf course greens

However, actions by government and industry in the late 1960's and early 1970's have significantly decreased mercury discharges from major industrial sources.

Relatively small amounts of mercury are still used in areas such as electrical and scientific equipment, amalgams in dental fillings, and fungicides for golf courses.

Mercury from various sources including burning of fossil fuels also enters the aquatic environment through precipitation.

c) Accumulation

Inorganic mercury entering a waterbody attaches to small sediment particles and much settles to the bottom of the waterbody. Microorganisms in these bottom sediments convert a portion of most mercury compounds to the organic or methylmercury form. Methylmercury is rapidly absorbed by fish either directly from the water passing over the gills or

from the ingestion of organisms in the diet of the fish. Fish absorb mercury rapidly and excrete it extremely slowly, therefore mercury gradually accumulates in fish. Methylmercury is incorporated into the protein of the fish, and is found in the liver, kidney and flesh.

The longer a fish has been exposed to mercury in the environment, the higher the mercury level will be. This is verified by the very good correlations found between increasing length of fish and increasing mercury levels in the fish flesh. The more mercury-contaminated food a fish consumes, the higher its mercury level will be. Walleye and northern pike are likely to contain higher levels of mercury than whitefish of the same size since walleye and pike are top predators, feeding on smaller fish which may also contain elevated mercury levels. Whitefish, on the other hand, feed "lower down" in the food chain, on a variety of aquatic insects and invertebrates which usually contain less mercury than do small fish.

Figure 1 shows the differences in mercury levels between species, using data on walleye, northern pike and whitefish from Separation Lake on the English-Wabigoon River system in Northwestern Ontario. These variations in mercury levels are primarily the result of the differences in feeding habits among fish species. As well, this figure shows the increase in mercury levels with increasing fish length, since mercury tends to accumulate in predatory fish as they grow.

Mercury is found in fish everywhere in the province, ie. there appear to be no "mercury-free" fish (even analyzed samples of museum fish dating back to the early 1900's contained mercury).

Figure 2 shows the wide variety of

Figure 1.

Figure 2.

naturally occurring mercury levels in walleye from three natural systems in Ontario (systems unaffected by industrial discharges). These differences in mercury levels stem from differences in physical and biological conditions within individual waterbodies.

There are several examples of Ontario lakes with mercury contamination caused by industrial discharges in the late 1960's and early 1970's. The declining levels of mercury in fish from these locations are a result of government action to halt the mercury discharges, and the resulting declines are still being closely monitored. In 1970 mercury discharges from a chlor-alkali plant on the St. Clair River contaminated the Lake St. Clair fishery. Commercial fishing was halted and anglers were advised to only "fish for fun" and not consume the fish. Action was taken to halt this industrial mercury input. Lake St. Clair

has been intensively monitored annually since 1970 and the levels of mercury in fish have declined dramatically so that now many sizes and species can be consumed. Figure 3 shows the decline in mercury across a range of fish lengths for walleye from Lake St. Clair for five selected years from 1970-1988.

A similar situation occurred after mercury discharges from a chlor-alkali plant at Dryden resulted in contamination of fish in the English-Wabigoon River system. Several lakes on the system have been annually monitored and the mercury levels in fish have continued to decline. Figure 4 shows the trend toward mercury lower levels in walleye from Separation Lake for four selected years from 1975-1987.

This comparison clearly shows that a system can slowly recover from mercury

Figure 3.

Figure 4.

contamination if the source is discovered and controlled.

d) Effects of Mercury on Human Health

As mercury is ingested it accumulates in the body, but if intake ends, levels begin to decline. Figure 5 shows the seasonal variation in mercury concentrations (using hair samples) for a heavy fish consumer, with the highest levels found during peak fish consumption in the summer months, followed by greatly reduced levels when fish is no longer a major portion of the total diet.

Humans eliminate methylmercury at a much faster rate than fish. However, there

have been documented cases of mercury poisoning in humans. An epidemic of mercury poisoning occurred in Minamata, Japan, where people consumed fish contaminated by methylmercury from a chemical plant discharging into Minamata Bay. This discharge was extremely hazardous because it contained mercury already transformed by the plant process from the inorganic form into methylmercury. Following this epidemic, the term "Minamata Disease" was applied to mercury poisoning.

Another epidemic of methylmercury poisoning occurred in Iraq in 1971-72. Several thousand people died after eating bread made from seed grain treated with

Figure 5.

a fungicide containing mercury.

In both cases, people accumulated more than 20 milligrams of mercury in their body before any effects of the poisoning became apparent. This level is much higher than the average 2-3 mg level of mercury normally found in Canadians (OMOE, 1978). The central nervous system is most affected by methylmercury and the dominant manifestations of poisoning are disturbances of co-ordination and sensory functions. Some signs of the poisoning include:

- lack of co-ordination
- feelings of "pins and needles"
- numbness of lips and mouth
- constricted visual field
- night blindness
- tremors
- deafness
- diminished taste and smell

It should be noted that many of these symptoms are common to other ailments not associated with mercury poisoning, and extensive medical testing is required to determine any case of mercury poisoning.

e) Mercury Consumption Guidelines

The consumption guidelines developed for use by Ontario anglers are based on Health and Welfare Canada guidelines supplemented by the World Health Organization and supported by medical evidence gained through the study of the methylmercury poisoning epidemics in Japan and Iraq.

The Ontario consumption guidelines, which provide site specific, species specific and length specific information, are published in the "Guide to Eating Ontario Sport Fish". The fish consumption guidelines for mercury concentrations found in fish are as follows:

- less than 0.5 parts per million (ppm) mercury : no consumption restrictions.
- between 0.5 and 1.5 ppm mercury : consumption restrictions based on fish consumption frequency.
- Women of child-bearing age and children under 15 should not eat any fish with mercury levels above 0.5 ppm.
- greater than 1.5 ppm mercury : no consumption advised.

These guidelines are based on the analysis of skinless, boneless dorsal fillets. It should be noted that various methods of cooking, or the trimming away of fat from the fish does not reduce the mercury content, since mercury, unlike organics such as PCBs and mirex, is stored primarily in the muscle, not in the fat.

Women of childbearing age and children under 15 should only consume fish with mercury content of less than 0.5 ppm, since the toxic effect of methylmercury is ultimately related to its concentration in the individual (based on body size). Therefore, the same mercury intake in a larger person would produce a lower concentration of methylmercury in the blood and tissues; in a smaller person or child it would produce higher concentrations.

The degree of methylmercury exposure in the mother which will cause behavioural and developmental changes in the infant is not known at present. Therefore, great care must be taken to avoid excessive exposure of the fetus to methylmercury. A woman in the childbearing years should avoid excessive intake of methylmercury not only during pregnancy but also some time beforehand. Mercury intake should also be minimal for breast-feeding mothers since mother's milk can be a source of methylmercury for the infant (OMOE, 1978).

2.2 Lead

Lead is a naturally occurring blueish or silvery grey soft metal, which can be easily cast, melted, rolled and extruded.

Lead enters the environment via three principal routes: atmospheric emissions, liquid effluents and solid waste material. The combustion of leaded gasoline is the largest source to the atmosphere, however this source is declining due to the reduction in the use of leaded gasoline. Municipal sewage and urban storm water runoff are the largest sources of lead to surface waters. Other activities which discharge lead effluents are: the manufacturing of electric storage batteries, metal plating, tank lining, lead smelting and lead shot manufacturing.

Lead discharged directly into natural waters tends to localize near the point of discharge due to the very low solubility of the compounds that are formed upon contact with water. Lead is rapidly removed from water when it passes through soil or is bound to particulates in water and settles to the bottom sediments. This is due to the high capacity of organic matter to bind the lead firmly. Because of this binding mechanism, lead concentrations in natural waters are generally low, and most lead is unavailable for accumulation by aquatic animals (WHO, 1977).

Studies have shown that aquatic invertebrate species generally accumulate lead to a greater extent than aquatic vertebrates. The pH of the water plays the most important role in the accumulation of lead by fish, with studies showing that almost three times more lead is accumulated from acidic waterbodies (pH 6.0) than from more normally encountered neutral or slightly alkaline waters (pH 7.5).

The sites of lead accumulation in fish (ie. the fins, gills and liver) are not altered by pH changes (Trotter, 1987).

The accumulation of lead in edible fish tissue does not appear to be a general problem in Ontario. One exception was the occurrence of biologically available alkyl lead in fish directly below an active industrial source. This occurred in Blue Church Bay, on the St. Lawrence River at Maitland, as the result of discharges from a tetraethyl lead production plant at Maitland. Intensive investigations in 1983 found that fish species in the Blue Church Bay area could potentially have elevated lead levels, and as a result, it was advised in the "Guide to Eating Ontario Sport Fish" that all fish species in the Blue Church Bay area be restricted for consumption. Attempts were made to reduce the losses of lead to the river in 1983-84, but these attempts were not adequate to sufficiently reduce the lead levels. Tetraethyl lead production at this plant ceased in 1985, and as a result, in 1986, the lead levels were reduced to background levels for sport fish from that part of the St. Lawrence River. As a result of the reduction in lead levels, the restricted consumption advice for fish from the Blue Church Bay area was removed from the "Guide" in 1986. Testing of surrounding areas in the St. Lawrence River indicated that there were no accumulated lead levels in any fish species sampled, therefore the elevated levels were limited to the immediate area around the plant discharge.

Figure 6 shows the average lead levels in yellow perch, white sucker and northern pike collected in Blue Church Bay from 1983-1986. The decline in lead levels in these species was a result of the shutdown of the tetraethyl lead plant at Maitland.

Figure 6.

At the other Ontario tetraethyl lead producer, located on the St. Clair River, no elevated levels of lead have been detected in the fish. This may be due to the rapid dispersion of the effluent in the St. Clair River, as well as control and treatment of the effluent.

Acute high lead intakes can severely damage the brain and the kidneys of adults or children, can cause abortions and can damage the male reproductive system. As well, there are potential dangers from chronic low level lead exposure for developing fetuses and young children, such as reduced birth weight, pre-term births, decreased IQs, and growth retardation (EPA Superfund Profile, 1987).

Routine analysis of sport fish for lead is carried out on fish from a number of Ontario locations, but elevated levels have not recently been detected. Consequently,

no sport fish in Ontario are presently restricted for consumption because of lead levels.

2.3 Other Metals

As well as mercury and lead, traces of other metals have been detected in Ontario sport fish samples. Metals which are routinely analyzed by the Ministry of the Environment laboratories include: arsenic, cadmium, chromium, copper, manganese, selenium, nickel and zinc. Because of their natural occurrence and their use by industry, these metals find their way into the aquatic environment.

While there are no federal guidelines for the levels of these other metals in fish, they are usually only detected in trace levels in Ontario sport fish. Occasionally, elevated levels of some metals have been detected, especially near mining sources (eg. elevated arsenic levels in fish from Moira Lake). However, based on the guidelines for levels in other foodstuffs, there appears to be no need to suggest restrictions on the consumption of fish.

Tables 1 and 2 give summary information on the principal sources of metals to the aquatic environment, the environmental pathways and fate in the aquatic environment, the bioaccumulation and bio-magnification of these metals in fish, and the applicable Provincial Water Quality Objectives (PWQO), which are set for the protection of all forms of aquatic life and all aspects of the aquatic life cycle.

Table 1.

Other Metals: Principal Sources to the Aquatic Environment and Environmental Pathways and Fate

Metal	Principal Sources to the Aquatic Environment	Environmental Pathways and Fate
Arsenic	smelting and refining of gold, zinc, lead, copper, silver and nickel; agricultural and domestic uses of arsenic	exists in a number of oxidation states and in both organic and inorganic forms(mainly inorganic); absorbed through gills and gut
Cadmium	Municipal sewage discharges; storm run-off; direct deposition by dust-fall and precipitation	may be bound to particles or in the dissolved state; accumulates more rapidly in sediments than in living organisms
Chromium	windblown soil, airborne particles from smelting and incineration	in water forms 2 principal ions - one quite mobile, while other is largely associated with particulate matter and subject to sedimentation; main absorption is through gills
Copper	sewage effluent and agricultural uses (fertilizers/pesticides); wastewater from pulp and paper mills, metal mines and refining industries	a major portion of copper in freshwaters may be adsorbed onto colloidal and particulate surfaces; accumulates in liver, gills and kidneys
Manganese	mainly degradation of rock	usually enters surface water in insoluble oxidized form, which settles to sediment and may be reduced by bacteria
Nickel	mining and smelting activities; fossil fuel combustion; dissolution of rock	occurs as soluble salts, suspended solids and organic complexes; accumulated in fish from food and water
Selenium	burning of coal; mining, smelting and refining of selenium; degradation of rock	can be easily converted to various organic compounds; trout can efficiently absorb ingested selenium

Table 1. (continued)

Metal	Principal Sources to the Aquatic Environment	Environmental Pathways and Fate
Zinc	natural weathering processes; air emissions from primary zinc production, wood combustion, waste incineration and iron and steel production	distribution varies with pH and alkalinity; concentrates in liver, kidney and gill tissue

Table 2.
Other Metals: Bioaccumulation and Biomagnification in Fish, and
Provincial Water Quality Objectives (PWQO)

Metal	Bioaccumulation	Biomagnification	PWQO (ug/L)
Arsenic	low	no	100
Cadmium	insignificant	no	0.2
Chromium	low	unknown	100
Copper	low	no	5
Manganese	low	no	not available
Nickel	insignificant	no	25
Selenium	rapid uptake by trout; bioconcentration decreases with increase in selenium	unknown	100
Zinc	low	no	30

Industrial Organics

2.4 PCBs

a) Properties

PCBs (polychlorinated biphenyls) are synthetically-produced chlorinated organic compounds, which do not occur naturally in the environment. They are relatively fire-resistant, very stable, do not conduct electricity, and are denser than water.

PCBs are extremely resistant to chemical and biological breakdown by natural processes in the environment, and therefore tend to persist for years in the natural environment.

PCBs can be completely destroyed only by burning under extreme heat (over 1100 degrees Celsius) or in the presence of certain combinations of chemical agents and heat (CCREM, 1986).

b) Occurrence

For many decades the hazardous nature of PCBs was not understood, and PCBs were routinely disposed of without precautions being taken. As a result, large volumes of PCBs were introduced into the environment by: open burning or incomplete incineration; direct entry or leakage into sewers and streams; vaporization from paints, coatings and plastic; and dumping in non-secure landfill sites and municipal disposal facilities. By the late 1970's, open-ended uses of PCBs were virtually eliminated. However, in spite of strict regulations, some PCBs have been illegally dumped either through negligence, ignorance or illegal activities (CCREM, 1986).

As a result, PCBs have been detected in samples of animal tissue from a number of

locations throughout the world. In Ontario low concentrations of PCBs have been found in fish from a number of locations remote from known sources, likely as a result of atmospheric fallout. The highest concentrations are found in the industrialized areas, most notably the Great Lakes, and particularly Lake Ontario.

c) Uses

PCBs were never manufactured in Canada, but were produced for North America in the United States between 1929 and 1977. PCBs were imported into Canada for a number of years for use as cooling and insulating fluids for electrical transformers and capacitors. Other uses, all of which were restricted in Canada in 1977, were as hydraulic fluids; surface coatings for carbonless copy paper; a plasticizer in sealants, caulking, synthetic resins, rubbers, paints, waxes, and asphalts; and as flame retardants in lubricating oils.

The continued use of PCBs in both Canada and the United States is allowed only in existing closed electrical and hydraulic systems. Under present Canadian legislation, PCB-filled electrical equipment is to be allowed to continue in use until the end of its service life. The equipment is then being replaced with either dry-type transformers or transformers containing an approved dielectric fluid such as silicone oils or transformer-grade mineral oil. While the transformers containing PCBs are still in service, strict maintenance and safe handling procedures, as well as regulatory control and close monitoring by provincial and federal governments, help ensure the safe operation of this equipment (CCREM, 1986).

d) Accumulation

Because of their chemical stability and their tendency to bioaccumulate in living organisms, PCBs are stored and concentrated in the environment. Since PCBs are soluble in fat tissue, but virtually insoluble in water, they can be stored and concentrated in fat tissue as they move up the food chain through fish, birds, and other animals, and eventually to humans who consume the fish (CCREM, 1986). Therefore, species of fish with high fat content, such as salmon, trout, carp and catfish, have, in some Ontario waters, accumulated PCBs to levels which cause consumption restrictions. Species such as northern pike or walleye, which are top predators but carry fat in separate fat bodies in the intestines, generally do not accumulate such high levels of organic contaminants such as PCB in their flesh.

PCBs are usually found in highest concentrations in fish sampled from Great Lakes locations, particularly Lake Ontario locations. Three figures are shown, to illustrate the differences in PCB levels between various Great Lakes locations, and between species in Lake Ontario.

Figure 7 shows the differences in PCB levels with length for the edible portion of chinook salmon from four Great Lakes locations.

Differences can be found between species which accumulate PCBs because of such factors as the residence time spent by the fish in the waterbody. Figure 8 shows the variation in PCB levels between four Lake Ontario salmonid species found in the Credit River area. The highest PCB levels in the edible portion samples were in the lake trout at sizes above 55 cm (22"). This is because lake trout have a slower growth rate and longer life span than the

Figure 7.

Figure 8.

other species. Therefore, larger lake trout have had longer time to accumulate PCBs. The chinook salmon grow to be much larger in a relatively short residence time (3-4 years), and therefore have not accumulated PCBs to as great an extent as the lake trout. There is little difference between the chinook salmon, coho salmon and rainbow trout at sizes up to 80 cm (32").

Figure 9 shows the PCB-length relationship for three non-salmonid species from a nearshore Great Lakes area (Hamilton Harbour). Although there are significant size differences between these three species, this figure shows the differences in PCB levels due to fat content, residence time, and feeding habits.

Figure 9.

Carp, which are fatty fish and therefore good accumulators of organic contaminants such as PCB and mirex, are also long-lived and associated with sediments which can

contain contaminants. Thus, older carp can accumulate high levels of PCB. The differences in PCB levels between the white perch and the black crappie can be related to different feeding habits. The white perch preys on smaller fish and is therefore higher in the food chain. The black crappie feeds to a much greater extent on larvae of aquatic insects and on plankton, which are lower down on the food chain. As a result, the levels of PCB in black crappie are lower than in the white perch.

Long-term monitoring of various Great Lakes locations has indicated that PCB levels have declined in Ontario sport fish as a result of the restrictions on PCB usage in the 1970's. Figure 10 shows the mean PCB levels from 1972-1988 for skinless, boneless dorsal filets of coho salmon from Lake Ontario at the Credit River. The

Figure 10.

annual mean has declined significantly

from the high levels, of over 10 parts per million in 1972, to about 1 ppm presently.

Figure 11 shows a decline in mean PCB levels in Lake Trout from Southern Lake Huron from 1976-1986. The PCB values are now well below the 2.0 parts per million consumption restriction guideline, so consumption of lake trout from this area is no longer restricted due to PCB levels.

Figure 11.

Occasionally, fish with elevated levels of PCBs have been found from inland locations because of industrial sources, spillage or road oiling. An example of this is Lake Clear in the Renfrew County area of southeastern Ontario. Results from routine sport fish samples taken in the late 1970's on Lake Clear indicated a potential PCB source to the lake. Intensive investigations followed, with analyses being done on the sport fish, forage fish, water, sediments and soils. These investigations

determined that at some previous time, oil containing PCBs had been used on the cottage road to suppress dust (up until 1978 road oiling with PCB contaminated oil was not uncommon, as transformer fluid was treated the same way as other waste oils). In 1984, over one million dollars was spent to remove parts of the Lake Clear road and place it in a secure containment vault. The effects of this remedial action are being monitored by continuing studies on Lake Clear.

Routine sampling of sport fish continues at many locations in the province to monitor PCB levels in the environment.

e) Effects of PCBs on Human Health

While there have been many laboratory experiments and studies which attempted to determine the full health effects of PCBs on humans, none has been definitive. However, animal studies have indicated that long-term exposure to PCBs can cause cancer, have immunotoxic effects and can severely affect reproduction. These animal studies have also shown cases of lipid peroxidation, increased serum cholesterol levels, and, in some species, liver damage.

Although PCBs are widely recognized as a potential hazard to human health, the full extent of the health implications is not known (CCREM, 1986). Contact with PCBs may cause skin rashes, swelling of eyelids, the darkening of nails, skin and mucous membranes, headaches or vomiting. Extensive exposure has resulted in chloracne, which is a painful and disfiguring skin condition.

As well, there is now limited evidence of human carcinogenicity from PCB exposure, particularly skin and liver cancer (IARC, 1987). Although the potential effects of PCBs on human reproduction

have yet to be totally ascertained, there are studies which link the ingestion of PCB-contaminated fish by pregnant women with infants of slightly lower birth weight, decreased gestational age and smaller head circumference (EPA Superfund Profile, 1987). The very long-term (multigenerational) effects of PCBs are still being studied (CCREM, 1986).

As a result of these animal studies and the potential effects on humans from PCB intake, very restrictive guidelines for the human consumption of sport fish containing PCB have been established by the federal government.

f) PCB Consumption Guidelines

Since there is some evidence that PCBs are human carcinogens, and the time lag between exposure to a cancer-causing agent and the development of a cancer may be 20-30 years in the case of human exposure, guidelines must be set conservatively low to protect public health (OMOE, 1978).

Of particular concern in the setting of guidelines is the protection of children, and pregnant or breast-feeding women. For pregnant women, exposure of the fetus to a chemical such as PCB is of special concern, especially when the chemical may be teratogenic to the fetus. As well, since PCB (which in humans is absorbed from the stomach and stored in the fatty tissue) can be excreted in human milk and may be carcinogenic to breast-fed infants, advisories are given to breast-feeding mothers not to consume any fish contaminated with PCB.

The guidelines published in the "Guide to Eating Ontario Sport Fish" are based on federal guidelines (established using the results of animal studies) for the consumption of commercial fish. These

guidelines suggest that fish with PCB levels above 2.0 parts per million should only be eaten by adults (except women of childbearing age) on an occasional meal basis (eg. long-term consumers should only consume these fish once or twice per month). Women of childbearing age (ie. pregnant women, women intending to become pregnant, or breast-feeding mothers), and children under 15 years of age should not consume fish which are indicated to have greater than 2.0 parts per million of PCBs in the edible portion of the flesh.

The guidelines established for PCBs, mirex and other potential carcinogens are arrived at after consideration of available data, generally from animal experiments. The level at which no observed effects occur are noted and extrapolation to human populations is carried out. In the case of cancer-causing agents, it is generally assumed that there is no level at which no effect is produced and that cancer risk increases proportionately to dose. This continuum of dose-response means that any guideline selected is necessarily arbitrary. The guideline therefore does not represent an absolutely safe level. Instead it is derived taking into account a variety of considerations leading to determination of a risk considered acceptable to society, with an effort to be sufficiently conservative to err on the safe side (OMOE, 1978).

The lab analyses of sport fish for contaminants is done on the skinless, boneless, lean dorsal fillet, and consumption guidelines are based on this portion of the fish. Persons consuming fish prepared in other ways (eg. whole fish, fish steaks, portions with skin and bone intact, belly fat etc.) should be aware that organic contaminants such as PCBs, mirex and 2,3,7,8-TCDD associate with fatty tissue

and may be at higher concentrations in whole fish, fish steaks etc. than the sample tested. Therefore, only skinless, boneless fillets, with the fat layer removed, should be consumed.

2.5 Mirex

a) Properties

Mirex is a synthetically-produced chlorinated carbon compound (composed of 22% carbon and 78% chlorine) which does not occur naturally in the environment.

Mirex is similar to PCBs in that it is extremely resistant to chemical and biological breakdown by natural processes in the environment.

b) Uses

Mirex was used primarily as an insecticide to treat large areas of the southern United States (primarily by aerial treatment) to control fire ants. Mirex (which was also known as "Dechlorane") was also used as a fire retardant in plastics, electronic components, caulking and fabrics. It was manufactured by Hooker (now Occidental) Chemical Co. in Niagara Falls, New York until the late 1970s.

In 1978, the U.S. Environmental Protection Agency banned all further uses of mirex. However, continued trace losses into Lake Ontario from the plant site and the waste disposal sites of the Occidental Chemical Company still may be occurring. Another industrial source which has contributed to the elevated mirex levels in Lake Ontario fish is located on the Oswego River in Oswego, New York.

c) Occurrence

Mirex was never produced in Canada, but was imported into southern Ontario by two companies in the 1960s for use as a flame retardant coating in their manufactured plastic products. Extensive studies were carried out at both Ontario sites and mirex has not been detected in the water or the fish in areas adjacent to these two former Ontario users.

The contamination of Ontario sport fish by mirex is limited to Lake Ontario. Extensive sampling of sport fish from other Great Lakes and inland locations have indicated that mirex is not a contaminant of concern in sport fish from locations other than Lake Ontario.

d) Accumulation

Mirex is a very stable compound which does not readily break down in the environment and tends to bioaccumulate in living organisms.

Mirex is soluble in fat tissue, and it has extremely low solubility in water. As a result, mirex can be stored and concentrated in fat tissue as it moves up the food chain through fish, birds, and other animals, and eventually to humans who consume the fish. Therefore species of fish with high fat content, such as salmon, trout, carp and catfish, have accumulated mirex to levels which may result in consumption restrictions. Species such as northern pike or walleye, which are top predators but carry fat in separate fat bodies in the intestines, do not accumulate such high levels of organic contaminants such as mirex in their edible tissues.

Mirex and PCBs are the two contaminants causing major consumption restrictions on Lake Ontario sport fish species with high fat content. In many Lake

Ontario locations the mirex and PCB levels in fish are continuing to decline. However, in some Lake Ontario locations, the mirex concentrations are continuing to remain at high levels without showing indications of a significant decline. As a result, mirex is most often the contaminant which limits consumption of Lake Ontario sport fish.

Figure 12 shows an example of the decline in mirex levels from the high levels in the 1970's to the much lower levels after 1980, using the mean annual mirex levels in the edible portion of rainbow trout from the Ganaraska River mouth area. The mean values are now below the 0.1 parts per million consumption restriction criterion.

Figure 12.

Figure 13 shows the mean annual mirex levels in coho salmon collected from the mouth of the Credit River from 1976-1988. There were only small fluctuations in the mean levels between 1976 and 1986,

however, the mirex levels have declined sharply between 1986 and 1988.

Figure 13.

Differences can be found between species which accumulate mirex, because of such factors as size and growth rate. Figure 14 shows the variation in mirex levels between four Lake Ontario salmonid species sampled at the mouth of the Credit River. The lake trout, which are slowgrowing, have the highest mirex levels for any given size of fish. The chinook salmon have the lowest levels for any given size. However, Lake Ontario chinooks grow to a larger size than the other salmonids, and at these larger sizes they accumulate mirex to levels similar to large lake trout.

e) Effects of Mirex on Human Health

Mirex has tested positive for carcinogenic effects in animal tests and it

Figure 14.

also produces teratogenic effects. No reports on accidental poisoning or occupational exposure and occupational health effects are available. In the absence of adequate data in humans it is reasonable, for practical purposes, to regard mirex as if it presented a carcinogenic risk to humans (IARC, 1979).

f) Mirex Consumption Guidelines

Since mirex may potentially be a human carcinogen, and the time lag between exposure to a cancer-causing agent and the development of a cancer may be 20-30 years in the case of human exposure, consumption guidelines must be set conservatively low to protect public health. Of particular concern is the protection of children, and pregnant or breast-feeding women. For pregnant women, exposure of the fetus to a chemical such as mirex is of special concern, especially when the

chemical may be carcinogenic or teratogenic (OMOE, 1978).

The guidelines published in the "Guide to Eating Ontario Sport Fish" are based on federal guidelines (established using the results of animal studies) for the consumption of commercial fish. These guidelines state that fish with mirex levels above 0.1 parts per million should only be eaten by adults (except women of childbearing age) on an occasional meal basis (eg. long-term consumers should only consume these fish once or twice per month). Women of childbearing age (ie. pregnant women, women intending to become pregnant, or breast-feeding mothers), and children under 15 years of age should not consume fish which are indicated to have greater than 0.1 parts per million of mirex in the edible portion of the flesh.

2.6 Dioxins and Furans

a) Properties

The terms dioxins and furans respectively refer to the families of 75 related chemical compounds known as poly-chlorinated dibenzo-p-dioxins (PCDDs) and 135 related chemical compounds known as poly-chlorinated dibenzofurans (PCDFs). PCDDs and PCDFs are often grouped together because they possess similar chemical structures, similar patterns of toxic and biological responses, and may share a common mechanism of action at the cellular level.

The most toxic forms of PCDDs and PCDFs are those containing four to six chlorine atoms, and the most toxic of all the isomers is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD).

PCDDs are relatively insoluble in water, moderately stable and highly persistent. Both PCDDs and PCDFs are more likely associated with suspended material or found in sediment than dissolved in the water column.

b) Occurrence

PCDDs and PCDFs are not produced intentionally but are by-products created in the manufacturing of other chemicals such as certain organochlorine pesticides, or as a result of incomplete combustion of mixtures containing chlorine atoms and organic compounds.

In Ontario, there is no current chemical manufacturing of 2,4,5-trichlorophenol, nor formulation of 2,4,5-T, and 2, 4-D herbicides or pentachloro-phenol or hexachlorophenol, chemicals with which PCDD and PCDF contamination has been associated.

Current sources of PCDDs and PCDFs in the Ontario environment are from incineration processes or the use of products which contain trace amounts of PCDDs and PCDFs. The 2,3,7,8-TCDD is generally only a small percentage of the total PCDDs and PCDFs present. The chief sources to Ontario fish are industrial sewers, pulp and paper effluents, municipal sewage sludge, or leakage from dumps.

c) Accumulation

PCDFs and PCDDs have been found in fish from all Great Lakes, with the highest levels found in fish caught at Saginaw Bay, Michigan (Lake Huron). In Ontario, environmental samples contain complex mixtures of PCDD and PCDF isomers. The highest levels found in sport fish are usually in Lake Ontario species such as salmon and trout, which have higher lipid

or fat levels. These contaminants are similar to organic contaminants such as PCBs and mirex in that they tend to accumulate in the fatty tissue of fish.

The Ministry of the Environment's dioxin laboratory became operational in late 1980. The analysis of fish for dioxin is an exacting, costly process which measures levels in extremely minute (parts per trillion) concentrations. This limits the number of fish samples that can be evaluated. Sampling to date has been concentrated in the Great Lakes and the Niagara River.

d) Effects on Human Health

Most of the toxicological studies involving dioxins and furans relate to 2,3,7,8-TCDD, the most toxic of the isomers.

2,3,7,8-TCDD is acutely toxic to most laboratory animals at extremely low doses. Teratogenic and carcinogenic effects have been noted in rats and mice exposed to this compound.

The most frequently documented response in humans to accidental, industrial over-exposure to TCDD is chloracne (painful skin lesions). The symptoms slowly decrease over a prolonged period of time.

Epidemiological studies to date do not present sufficient evidence to establish a causal relationship between exposure to PCDDs and PCDFs and a chronic human health effect relating to carcinogenesis, coronary disease or impairment of the immune system (OMOE, 1985).

e) Consumption Guidelines

The guideline for the consumption of

sport fish containing 2,3,7,8-TCDD is 20 parts per trillion. This value is based on federal guidelines (established using the results of animal studies) for the consumption of commercial fish. These guidelines suggest that fish with levels of 2,3,7,8-TCDD above 20 parts per trillion should only be eaten by adults (except women of childbearing age) on an occasional meal basis (eg. long-term

consumers should only consume these fish once or twice per month). Women of childbearing age (pregnant women, women intending to become pregnant, or breast-feeding mothers), and children under 15 years of age should not consume fish which are indicated to have greater than 20 parts per trillion of 2,3,7,8-TCDD in the edible portion of the flesh.

The chief sources of PCDDs and PCDFs to Ontario fish are industrial sewers, pulp and paper effluents, municipal sewage sludge, or leakage from dumps.

Pesticides

2.7 DDT

DDT and its derivatives DDD and DDE are chlorinated hydrocarbon pesticides which were developed during the Second World War, and were used as insecticides for agricultural and public health use. They are highly stable compounds which consequently break down very slowly in the natural environment.

Since DDT in fish is broken down enzymatically mainly to DDD and DDE, and fish specimens could contain mixtures of these DDT metabolites, they are normally analyzed for the three major components, ie. DDT, DDD and DDE.

DDT is similar to other organic contaminants such as PCB and mirex in that it tends to accumulate in the fat tissue of fish. Similar to other contaminants, the concentrations of DDT in fish have been observed to increase with increasing fish length.

In the 1960's, evidence of DDT's persistence in the environment and toxicity to non-target species began to appear. Studies indicated that, in some fish species such as lake trout, there was a loss of viability in the eggs because of DDT accumulations. Such impacts on the environment led to restrictions in the mid 1960's on the use of DDT. In 1969, under provisions of Ontario's Pesticides Control Act, the use of DDT was limited to very specific purposes and only by special permit. No new permits have been issued for a number of years.

Because of these restrictions on its use, the levels of DDT in Ontario sport fish have declined substantially to very low levels.

Figure 15 shows an example of this decline, using lake trout from Lake Simcoe. This example was chosen because of the very early (1967 and 1970) DDT results, which were at high levels, well above the 5.0 parts per million consumption

Figure 15.

guideline. The levels had dropped off markedly by the late 1970's, and by 1983 were very low, indicating that DDT was no longer a contaminant of concern.

DDT is moderately acutely toxic to humans and other organisms. Because it is highly persistent in living organisms, the major concern over DDT toxicity is related to its chronic effects. Based on positive evidence of carcinogenicity in animal

studies, DDT is considered to be a possible carcinogen in humans (IARC,1987).

The guideline for the consumption of Ontario sport fish containing DDT is 5.0 parts per million, based on guidelines set by Health and Welfare Canada for the safe consumption of commercial fish. However, because of the substantial reductions in DDT levels, no Ontario sport fish samples in recent years have exceeded or even approached this guideline. Consequently, although it is still routinely monitored, DDT is not a contaminant of concern in Ontario sport fish.

2.8 Toxaphene

Toxaphene is a complex organochlorine insecticide which has been under restricted use in Ontario since 1973. It is registered by Agriculture Canada for the control of flies and ticks on beef cattle, sheep and horses. Prior to 1973, it had also been used experimentally as a piscicide to eradicate coarse fish. In the United States, toxaphene was used in large quantities mainly as an insecticide on cotton crops, and also as a herbicide in soyabean crops. However, in 1982, concerns by the U.S. about toxaphene's possible impact on fish led to restrictions in its use.

Adverse effects in fish attributed to toxaphene are stunted growth and skeletal fragility. Animal tests indicated that toxaphene caused liver cancer in mice. Because of a lack of adequate evidence of carcinogenicity in humans, toxaphene has been classified as a possible human carcinogen (IARC,1987). As well, toxaphene has a number of toxic effects on humans, especially on the central nervous system and skin, and can cause nausea, convulsions and unconsciousness.

The fish consumption guideline for toxaphene is set at 3 ppm by Health and Welfare Canada.

However, toxaphene, which is tested routinely in sport fish from a number of Ontario locations, has been found only at levels very far below this guideline value or is not detected. As a result, there have been no restrictions on consumption of Ontario sport fish because of toxaphene levels.

2.9 Chlordane

Chlordane is a highly persistent organochlorine insecticide that can take the form of an oil-type solution, emulsifiable concentrates, granules, dusts or wettable powder. Chlordane was used primarily for the control of termites and carpenter ants, as well as for agricultural purposes in the control of soil pests such as the corn rootworm and the strawberry root weevil.

Concerns about the persistence of chlordane in the environment led to restriction in its use for agricultural purposes in the late 1970's. It was then still available for home gardening use and by permit to licenced pesticide personnel for termite control. In 1985, the sale of chlordane was curtailed for the domestic market, but it was still available for termite control. However, its production was discontinued in the United States and consequently chlordane is now unavailable.

Chlordane is subject to bioaccumulation in the aquatic food chain.

Figure 16 shows the mean annual chlordane levels for the edible portion of coho salmon in Lake Ontario at the Credit River for the period between 1976 and 1988. As a result of the initial restrictions

placed on the agricultural use of chlordane, the levels in the coho salmon dropped off markedly beginning in 1979, and continue to remain low.

Figure 16.

Chlordane is considered one of the most hazardous pesticides (NAS,1977). It is highly persistent and is readily stored in fat tissue. Therefore, it has the potential for biomagnification in the food chain. The principal human health effects are central nervous system effects such as tremors, convulsions and death, and blood diseases such as leukemia and aplastic anemia.

The United States Food and Drug Administration has established a consumption guideline of 0.3 parts per million chlordane in fish. Routine analysis of chlordane in sport fish at a number of Ontario locations in recent years has shown that chlordane values are at such low levels

that they would not affect the consumption of Ontario sport fish.

2.10 Other Pesticides

a) Hexachlorobenzene (HCB)

HCB is a colourless compound formed as a by-product from the manufacturing of chlorine, perchloroethylene, carbon tetrachloride, trichloroethylene, and other chlorinated hydrocarbons.

It is used as a fungicide in dust or powder form to control fungal diseases in cereal grains (mainly on wheat seed for planting). Other uses are as a plasticizer for polyvinyl chloride, as well as a flame retardant.

In the aquatic environment, HCB is extremely hydrophobic, and is quickly absorbed into non-aqueous fractions such as sediments and biological tissue. HCB appears to have little effect on aquatic organisms, but a high bioaccumulation factor has been demonstrated in catfish. Among the various Ontario sport fish tested for HCB, carp and channel catfish generally have the highest HCB levels in the edible portion of the flesh.

Animal studies have shown HCB to be a potential mutagen as well as a carcinogen. In humans, HCB could cause skin irritations and enzyme disruptions (Sittig,1985).

While the federal government has not established guidelines for HCB, the U.S. Environmental Protection Agency has established a fish consumption guideline for the protection of human health. This guideline is 6.4 ppb of HCB in the edible portion of fish tissue.

Routine analysis of HCB in Ontario sport fish has shown that HCB is found at low levels or is not detected at most locations. Higher levels have been found in some St. Clair River sport fish.

b) Aldrin

Aldrin is a pesticide which takes the form of a brown solid or solution.

It is used primarily for agricultural purposes to control soil insects, and, as well, for pest control uses including termites around building.

Significant bioaccumulation through the food chain probably does not occur because aldrin is rapidly converted to dieldrin in aquatic organisms. The half-life of aldrin is a few hours to a few days. However, dieldrin is a very persistent, fat-soluble toxic chemical, which undergoes biomagnification through the food chain.

Animal tests were positive for teratogenicity and aldrin is a potential carcinogen in animals and humans. In humans, aldrin may affect the central nervous system, as well as the liver, kidneys and skin (Sittig,1985).

No federal government guidelines have been established for aldrin. However, routine analysis of aldrin in Ontario sport fish has shown that aldrin is only found at low levels or is not detected.

c) Lindane

Lindane is a colourless solid pesticide with a saturated, chlorinated, cyclic hydrocarbon structure.

The major use of lindane is in seed treatments, but it is also used in soil treatment, foliage applications and for

wood protection.

Lindane is only slightly bioaccumulated in aquatic organisms. Up to 90% of lindane is biodegradable by anaerobic bacteria in four days and is transformed to chlorine-free metabolites.

Lindane has tested positive as a carcinogen in animal studies. In humans, lindane may act on the central nervous system, blood, liver and kidneys (Sittig,1985).

No federal guidelines have been established for lindane, however, lindane has only been found in very low levels in Ontario sport fish.

d) Heptachlor

Heptachlor is a pesticide which takes the form of a light tan waxy solid.

It is applied as a soil treatment, a seed treatment and directly on foliage, to control soil pests, household insects, and domestic animal pests.

Heptachlor shows strong tendencies for bioaccumulation, and can be highly toxic to aquatic life. It can be biotransformed by oxidation to heptachlor epoxide, its principal metabolite, which is more acutely toxic than heptachlor.

There is limited evidence that heptachlor has reproductive and teratogenic effects in animals (EPA Superfund Profile,1987).

No federal guidelines have been established for heptachlor. However, heptachlor has only been found in very low levels in Ontario sport fish.

Other Substances

2.11 Octachlorostyrene (OCS)

OCS is a colourless oily liquid.

OCS is produced from impurities in the manufacturing of chlorine from electrolysis of a saturated sodium chloride solution. Prior to the 1970's, the process employed graphite electrodes which are subject to decomposition, producing a waste "taffy" mixture of chlorinated organics. Since then a widespread conversion to metal electrodes has taken place with subsequent reductions in OCS production.

OCS is also produced as a by-product in industrial processes involving carbon and chlorine in high temperature reactions, such as those which produce carbon tetrachloride and tetrachloro-ethylene. These compounds are presently produced at Dow Chemical Corporation in Sarnia. Dow is currently making efforts to isolate the contaminated fraction and treat it as required.

The bioaccumulation potential of OCS is very high. Carp and channel catfish have generally been found to have the highest OCS levels among tested Ontario sport fish. Figure 17 shows the mean annual OCS concentrations in the edible portion of channel catfish from Lake St. Clair. Little variation has occurred in the OCS levels from 1981 to 1986.

There appears to be little information available on the toxic effects of octachlorostyrene in animals or humans. Acute doses of octachlorostyrene produced changes in liver weights and enzyme activities in rats (Chu, 1982).

Although there are no federal guidelines for OCS, low levels are found in Ontario

sport fish at most locations tested.

Figure 17.

2.12 New Substances

The Sport Fish Contaminant Monitoring Program monitors as many substances as practically possible. New substances are added to the list of chemicals analyzed in sport fish as concern for their levels in the environment mounts and analytical methods become available to measure low levels of these chemicals.

Procedures have recently been added for incorporating a range of chlorinated phenols, chlorinated benzenes and polynuclear aromatic hydrocarbons. To date, these substances have been found occasionally in fish, usually near a known or suspected source, but at very low levels that are unlikely to effect consumption.

The new substances which have recently

been incorporated include:

2,4,6 - Trichlorophenol
2,4,5 - Trichlorophenol
2,3,4 - Trichlorophenol
2,3,5,6 - Tetrachlorophenol
2,3,4,5 - Tetrachlorophenol
Pentachlorophenol
Hexachloroethane
Hexachlorobutadiene
1,3,5 - Trichlorobenzene
1,2,4 - Trichlorobenzene
1,2,3 - Trichlorobenzene
1,2,4,5 - Tetrachlorobenzene
1,2,3,4 - Tetrachlorobenzene
Pentachlorobenzene
2,4,5 - Trichlorotoluene
2,3,6 - Trichlorotoluene
Dibenzo(a,h)anthracene
Benzo(g,h,i)perylene
Naphthalene
Acenaphthylene
Acenaphthene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(k)fluoranthene
Benzo(b)fluorene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene

3.0 Glossary of Terms

Acute toxicity:	A toxic effect that is produced within a short period of time, usually 24 to 96 hours. Although the effect most frequently considered is mortality, the end result of acute toxicity is not necessarily death. Any harmful biological effect may be the result.
Anaerobic bacteria:	any bacteria that can survive in the partial or complete absence of oxygen.
Bioaccumulation:	uptake and retention of environmental substances by an organism from both its environment (ie. directly from the water) and its food.
Biodegradable:	can be broken down by microorganisms.
Biomagnification:	the magnification of a chemical along the food chain.
Carcinogenic:	capable of producing malignant tumors.
Chronic toxicity:	a toxic effect produced in an organism as a result of lengthy exposure to a toxin. The end result of chronic toxicity can be death although the usual effects are sublethal. These effects are reflected by changes in the productivity and population structure of the community.
Emulsifiable:	able to form stable emulsions with water.
Food chain:	the scheme of feeding relationships which unites the member species of a biological community.
Forage fish:	small fish preyed upon by larger fish.
Half-life:	the time required to reduce the concentration of a material by half.
Hydrophobic:	lacking affinity for water.
Immunotoxic effects:	can suppress, or produce toxic effects on, the immune system.
Microgram per Litre: ($\mu\text{g/L}$)	for practical purposes, the equivalent of parts per billion (ppb).

Glossary of Terms (continued)

Oxidation:	a chemical reaction that increases the oxygen content of a compound.
Piscicide:	chemical used to kill a target fish species.
ppm:	parts per million.
Soluble:	capable of being dissolved.
Teratogenic:	can produce irreversible birth defects, or anatomical or functional disorders as a result of an effect on the developing embryo.
Toxicity:	quality, state or degree of the harmful effect resulting from alteration of an environmental factor.

4.0 Bibliography

Callahan, M.A. et al. 1979, Water-Related Environmental Fate of 129 Priority Pollutants. Volume 1. United States Environmental Protection Agency. Washington.

Canadian Council of Resource and Environment Ministers (CCREM). 1986, The PCB Story. Toronto.

Chu, I. et al. 1982, Acute and Sub-Acute Toxicity of Octachlorostyrene in the Rat. Journal of Toxicology and Environmental Health. Volume 10(2).

de Barros, C. 1985, Handbook of Potential Contaminants in the Aquatic Environment. Ontario Ministry of the Environment. Toronto.

D'Itri, P.A. and F.M. 1977, Mercury Contamination: A Human Tragedy. John Wiley and Sons.

Health and Welfare Canada. 1984, Methylmercury in Canada: Exposure of Indian and Inuit Residents to Methylmercury in the Canadian Environment. Volume 2. Ottawa.

International Agency for Research on Cancer (IARC). 1979, IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Some Halogenated Hydrocarbons. Volume 20. Lyon.

International Union of Pure and Applied Chemistry (IUPAC), Applied Chemistry Division, Commission on Terminal Pesticide Residues, IUPAC Reports on Pesticides. Toxaphene (Camphechlor): A Special Report. Prepared for Publication by F. Korte, I. Scheunert, H. Parlar. Pergamon Press.

Marier, J.R. and J.F. Jaworski. 1983, Interactions of Selenium. National Research Council of Canada, Division of Biological Sciences. Ottawa.

National Academy of Science. 1977, Drinking Water and Health. Volume 1. Washington.

National Research Council of Canada. 1978, Effects of Arsenic in the Canadian Environment. Associate Committee on Scientific Criteria for Environmental Quality. Ottawa.

National Research Council of Canada. Chlordane: Its Effects on Canadian Ecosystems and its Chemistry. Subcommittee on Pesticides and Related Components. Ottawa.

National Research Council of Canada. 1976, Effects of Chromium in the Canadian Environment. Associate Committee on Scientific Criteria for Environmental Quality. Ottawa.

National Research Council of Canada. 1981, Effects of Nickel in the Canadian Environment. Associate Committee on Scientific Criteria for Environmental Quality. Ottawa.

Newell, A.J., D.W. Johnson, and L.K. Allen. 1987, Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife. New York State Dept. of Environmental Conservation.

Ontario Ministry of the Environment. 1988, Guide to Eating Ontario Sport Fish. Toronto.

Ontario Ministry of the Environment. 1978, Health Implications of Contaminants in Fish. Toronto.

Ontario Ministry of the Environment. 1985, Scientific Criteria Document for Standard Development No.4 - 84. Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans. Toronto.

Sittig, M. 1985, Handbook of Toxic and Hazardous Chemicals and Carcinogens. Second Edition. Princeton University.

State of Michigan, Critical Materials Register 1979. Publication Number 4833-5323 Environmental Services Division, Michigan Department of Natural Resources. P.O. Box 30028, Lansing, Michigan, 48909.

Trotter, D.M. 1987, A Review of the Aquatic Effects of Metals, prepared for Ontario Ministry of the Environment, Water Resources Branch. Toronto.

U.S. Department of Health and Human Services. 1981, Second Annual Report on Carcinogens.

U.S. Environmental Protection Agency. 1987, Superfund Chemical Profiles. Toxicological profiles prepared by the Agency for Toxic Substances and Disease Registry, United States Public Health Service.

United States Environmental Protection Agency. 1989, Assessing Human Health Risks for Chemically Contaminated Fish and Shellfish: A Guidance Manual. EPA-503/8-89-002. Washington.

World Health Organization. 1977, Environmental Health Criteria 1 - Mercury. Geneva.

World Health Organization. 1977, Environmental Health Criteria 3 - Lead. Geneva.

Worthing, C.R., editor. 1983, The Pesticide Manual - A World Compendium. The British Crop Protection Council. Croydon, England.