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Parlous POPs:

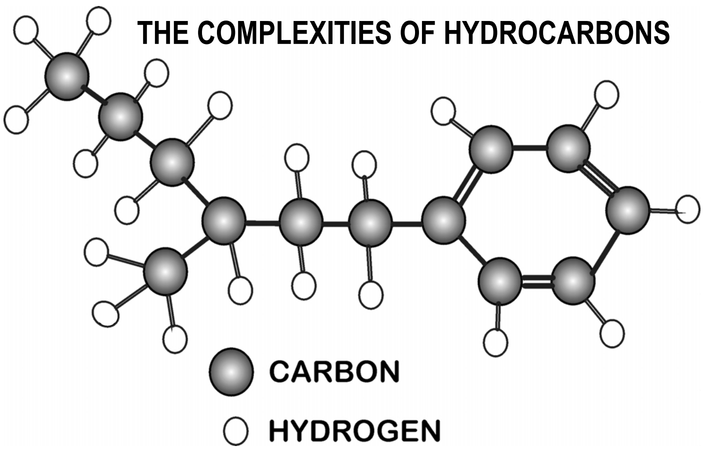
Persistent Organic Pollutants in the Bay of Fundy

A Cornucopia of Contaminants

No one knows exactly how many different chemicals are released into the environment each year from manufacturing products, extracting resources, operating farms, protecting forests and performing everyday domestic activities. Charles Auer, a toxic chemicals specialist with the U.S. Environmental Protection Agency, estimates that over the last 25 years the U.S. alone has approved over 40,000 different compounds for public use. United Nations officials report that at least 1,500 additional ones are produced each year as chemists synthesize novel compounds and chemical engineers develop new processes for manufacturing the countless products that sustain our economy and enhance our standard of living. More than 1100 different pesticides alone have common names approved by the International Standards Organization (ISO) and listed in their *"Compendium of Pesticide Common Names"*. Many of these chemicals eventually find their way into the water, air and soil, either intentionally or unintentionally, hence becoming environmental contaminants. Some have no detectable effects on non-target animals and plants, others are highly toxic at very low concentrations, while the majority lie between these extremes. In studying the sources, fates and biological effects of this large, unwieldy and varied array of very different contaminants, scientists usually group them in convenient categories based on similarities in composition, behaviour, intended use, biological effects, or some other common distinguishing characteristics. For example, there are "heavy metals", "petroleum hydrocarbons", "endocrine disrupting compounds, "carcinogens", "insecticides", "herbicides" and a myriad other groupings, many of which overlap one another. One of the largest, most varied and environmentally worrisome of these clusters of chemical contaminants goes by the innocuous sounding acronym, POPs.

Pernicious POPs

Persistent Organic Pollutants - three simple words, but each charged with ominous implications for all living organisms. Consider the term organic, which means "relating to or derived from living organisms". Organic compounds underlie the structure and activity of all living organisms. Life depends on a wide array of complex organic molecules, comprised chiefly of linked atoms of carbon, with appended hydrogen atoms, known collectively as hydrocarbons. The carbon atoms can link together to form chains, rings, spirals and a host of other complex structures ranging in size from just a few to hundreds of thousands of atoms. Over billions of years of evolution, organisms have elaborated and exploited this remarkable complexity of hydrocarbon molecules to form many natural materials that they need to create, develop and maintain themselves. They have evolved elaborate chemical processes for accumulating, transporting, storing, breaking down, transforming and constructing specific hydrocarbon molecules to suit their



needs. As part of the endless process of recycling organic matter through birth, life, death, decomposition and new life, organisms have also developed ways to break apart unwanted hydrocarbons into simpler molecules that can be reincorporated into the cycle of life.

Researchers studying the structure and function of natural hydrocarbons soon learned that in the laboratory they could be manipulated and transformed into other chemical compounds with new and unusual properties. The POP's of concern are synthetic chemicals that never existed in the natural world; they were created by human ingenuity within the past century. They include some of our most economically valuable compounds but also some of the most dangerous to living organisms. For example, by replacing some of the hydrogen atoms in a natural hydrocarbon with chlorine atoms, chemists created an array of new and novel chemical compounds collectively called "chlorinated hydrocarbons". By the mid 1900s, this discovery had launched what some scientists call the "organochlorine era". Chlorinated hydrocarbons such DDT, chlordane, lindane, toxaphene and a host of similar pesticides promised to virtually eradicate unwanted insects and other pests threatening our health, crops and forests. Most POPs, including chlorinated hydrocarbons, possess another property that enhances both their usefulness and their danger.

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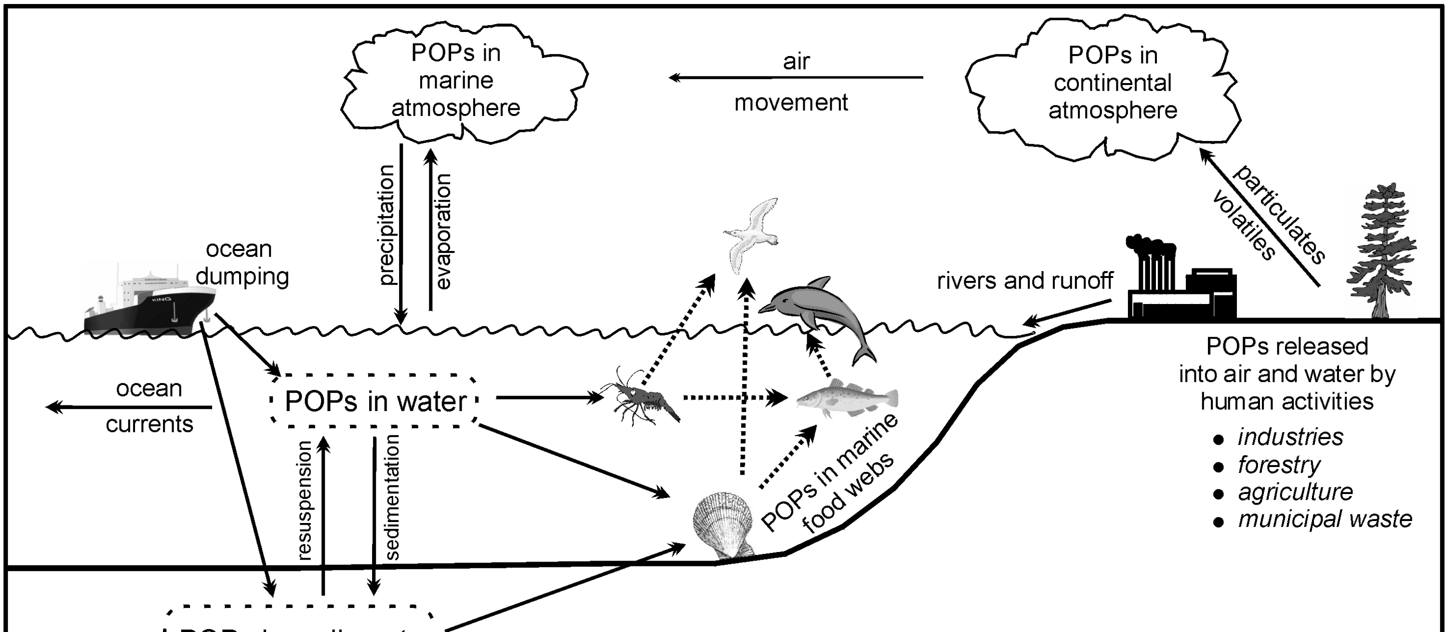
They are very persistent or long lasting in the environment, far beyond the time of activity needed to control pests. Most natural hydrocarbons degrade quickly to basic elements by normal bacterial activity and other natural processes. However, the presence of chlorine, bromine or similar elements in their structure makes POPs more stable and resistant to breakdown by normal biological processes.

The new chemical pesticides are remarkably effective, and dangerous, because of their insidious nature, their ready absorption by organisms and their toxicity at low concentrations. The physiological processes of the pest organisms readily take up, process, transform, metabolize and excrete a wide array of natural hydrocarbons. The pesticide molecule, with its unfamiliar chlorine atoms, is just sufficiently similar to a natural hydrocarbon that it is taken up and treated as such by the organism's metabolic machinery. However, the intrusive chlorine disrupts the critical biochemical reactions and the physiological processes dependent on them, causing the organism to sicken and die. What the insect naively accepts as a typical, easily metabolized hydrocarbon is in reality a deadly Trojan horse. The organic nature of these pesticides, along with their "3P properties" (persistence, partitioning, potency), are what makes them so effective and so deadly. However, what was not fully recognized when these chemicals were indiscriminately and widely used in the 1940s, 50s and 60s was that their toxicity is seldom limited to insects or weeds. Most are so called "non -selective" toxicants and all living things, including humans, are vulnerable to some degree.

Partitioning POPs

When chemical substances, including POPs, are released into the environment they do not normally spread uniformly but tend to accumulate in certain parts of the ecosystem that scientists refer to as "environmental compartments". These may include the air, water (fresh and salt), bottom sediments,



Partitioning of POPs in Coastal Waters

soil and tissues of living organisms, but are often somewhat arbitrary. A scientist might define the compartments for a particular study as deep water, mid water and shallow water, or coastal water and offshore water; while the compartments for another study might be phytoplankton, zooplankton and fish. The key point is that the proportion of a chemical compound that accumulates in the different compartments (scientists refer to the process as "partitioning") depends on the particular chemical and its properties. Some chemicals are attracted to suspended particles, quickly adsorb onto sediments and eventually descend to the seafloor. Others are volatile and enter the atmosphere as a gas. Highly water-soluble materials, such as acids and alcohols, tend to remain in the water column. Some compounds, especially POPs, are only poorly soluble in water but dissolve readily in lipids (fats and oils). Many marine organisms contain large amounts of lipids, so it is not surprising that POPs tend to accumulate preferentially in their tissues.

POPs may enter the tissues in a variety of ways. They can be absorbed from the water through membranous tissues such as the skin, gills and lining of the gut, or be extracted from the air in the lungs. POPs in an animal's food may be readily absorbed into the body through the lining of the digestive system and either metabolized or stored in body fats. A large quantity of lipid is required for the production of eggs, the development of embryos, and in the case of mammals, the production of milk to suckle young. Hence, these are important ways in which POPs can be transferred from a female of some species to her young. This was clearly shown by studies of DDT in harbour porpoises in the Bay of Fundy. Concentration of DDT in the blubber of males increased with age, as they consumed more and more of it with their food. However, in female porpoises the amount decreased with age because they transferred much of the DDT to their fetuses and calves; pregnant and lactating females had reduced levels of DDT while calves had high levels.

POPs in Populations

POPs are readily taken up by marine organisms and incorporated into the ocean's food chains. This is of great concern, not only because the chemicals can harm marine plants and animals and upset the productivity and integrity of ocean ecosystems, but also because of the potential threat to human health from contaminated seafood. Most POPs interfere with many metabolic processes of cells and tissues, causing an exceptionally wide range of biochemical, physiological, behavioural and clinical problems (see table). Factors that influence their toxicity to organisms include their concentration in the environment, the ease with which they are taken up by different tissues, the length of exposure, the manner in which they interact with biochemical and physiological processes, and the ability of organisms to break down and excrete them.

It is particularly worrisome that many POPs are carcinogens and induce cancerous growth in various tissues and organs. Others are teratogens and cause the body's developmental processes to go awry, producing dysfunction and malformation of parts of the body during development and growth. Furthermore, critical biological processes in living organisms, such as growth, development and reproduction, are regulated by chemical messengers, called hormones, which are released into the blood stream at appropriate times by organs or tissues. These circulating messengers attach to specific receptor cells of tissues or organs elsewhere in the body, causing them to respond in a very specific way. These receptors respond only to molecules with a particular structure. Such integrated biochemical control mechanisms involving hormones are called endocrine systems. Many scientists are concerned by the discovery that some POPs being released into the environment are sufficiently similar in structure to some hormones that, once they get into the tissues of organisms, they fool the hormonal receptors into responding to them as if they were the corresponding hormones. They may bind to the receptor sites and cause a physiological response at an inappropriate time. Or, they may attach to the receptor and block the attachment of normal hormone molecules, although their slight structural differences prevent the receptor from launching the usual physiological response. Either way, the resulting effects on endocrine regulated biological processes such as growth, development or reproduction can be severe. Studies so far have only looked at a small number of possible endocrine-disrupting compounds acting on a few types of organisms; the overall ecosystem-wide threat is thus far from clear. Nevertheless, the detection of low levels of more

SOME EFFECTS OF POPs ON LIVING ORGANISMS

[Based on a review of the literature]

FEATURE	EFFECTS	POPs IMPLICATED
Nervous system	Altered behaviour	PAHs, PBDEs
	Memory impairment	PBDEs
	Learning impairment	PBDEs
	Narcosis	PAHs
	Nerve function impairment	dioxins, chlordane, DDT, DDE, dieldrin, HCB, lindane, PCBs, toxaphene
Reproduction	Reproductive impairment	PAHs, PCBs, HCB, dioxins, furans, DDT, DDE, HCH, chlordane, dieldrin, lindane, toxaphene, heptachlor, mirex, TBT
	Egg shell thinning in birds	DDT, DDE, HCH
Growth and development	Developmental impairment	PCBs
	Deformities	HCB, PAHs, PCBs
	Cancerous growths	PAHs, dioxins, chlordane, DDT, DDE, dieldrin, HCB, lindane, PCBs, toxaphene, HCH, mirex
	Growth impairment	PCBs
	Embryonic development	PCBs
	Birth defects	dioxins
Tissue structure and function	Enzyme activity alteration	HCB, PBDEs, PCDDs, PAHs, DDE,
	Tissue disorders	PAHs
	Liver/kidney damage	chlordane, DDT, DDE, dieldrin, HCB, lindane, PCBs, toxaphene
Hormone system	Endocrine system disruption	PAHs, PBDEs, TBT, chlordane, dieldrin, HCB, PCBs, toxaphene, furans
Immune system	Immune system impairment	dioxins, PCBs, chlordane, DDT, DDE, dieldrin, HCB, toxaphene
Metabolism	Inhibition of photosynthesis	HCB

and more potentially endocrine disrupting chemicals in our coastal waters is cause for great concern, if they are being bioaccumulated by organisms across the food webs.

Production of POPs

POPs enter the environment from many different sources. Prior to the industrial revolution there was a steady input of a relatively small number of different POPs, such as the PAH's (polyaromatic hydrocarbons) that are produced by natural processes, such as volcanic activity, crude oil seeps and forest fires. While such natural inputs continue, they are now generally small, both in the quantities and the variety of different chemicals, compared to the contributions from human activities. The concentrations of POPs in the environment are typically very much higher near large industrialized urban centres compared to remoter rural areas. For example, in the Gulf of Maine, the Gulf Watch mussel-monitoring program reveals that the levels of some POPs (as well as other toxic chemicals) are much higher in coastal waters of the southern Gulf than in the northern Gulf and Bay of Fundy. However, currents of air and water can carry significant quantities of many POPs over most of the globe, even to the remotest places with no local human inputs.

Which human activities have introduced such significant quantities of so many POPs into our global environment? The most obvious is the spraying, from the air or from the ground, of large areas of our forests and farmlands with various toxic mixtures to control a wide range of fungal, plant and insect pests. Some of these chemicals eventually find their way, directly or indirectly, into soil, lakes, rivers and coastal waters. Some industries are also still releasing large amounts of POPs into the air or water, even after spending millions on waste treatment. These include pulp and paper mills, producers of chlorinated chemicals, manufacturers and users of dry cleaning compounds, and producers of other products that use halogenated hydrocarbons in their manufacturing processes. An example of the latter is the widespread use of polybrominated diphenyl ethers (PBDEs) as a flame retardant in products such as upholstered furniture. More rigorous safety regulations enacted in recent decades have resulted in a growing use of these compounds to reduce the flammability of many household and industrial products. Recent estimates suggest that about 70,000 tonnes of PBDEs are produced in North America each year. The quantities in the environment have risen steadily in recent decades and have been detected in soil, water, air, fish, birds and marine mammals and are also being absorbed by humans from their food. The production, refining and use of crude oil and its various products also introduces a variety of POPs, particularly PAHs into the environment. In addition, the incineration of household, medical and industrial wastes releases a variety of POPs.

PCBs

PCBs are chemicals produced in the laboratory that were never found in environment prior to the 20th century. There are over 200 known PCB congeners, each a slight variant on the chlorinated biphenyl rings. They are oily substances that are not very chemically active, don't burn and don't break down when exposed to heat or pressure. They have high resistance, don't readily conduct an electric current and thus make excellent insulators. These characteristics make them ideal for use in electrical and industrial equipment. They were first used primarily as insulating fluids in electrical transformers and capacitors but were subsequently found to be useful as fluids in hydraulic systems, compressors, heat transfer systems, and as coolants for electrical motors, as casting wax, pigments, as ballast in fluorescent lights and a variety of other uses. Most industrial PCB formulations are a mixture of 60 to 90 different congeners, differing only in the number and location of chlorine atoms. The most stable and useful PCB compounds are those with the greater number of chlorine atoms in their makeup. Ironically and unfortunately, these are the ones that also pose the greatest threat to the environment and to human health.

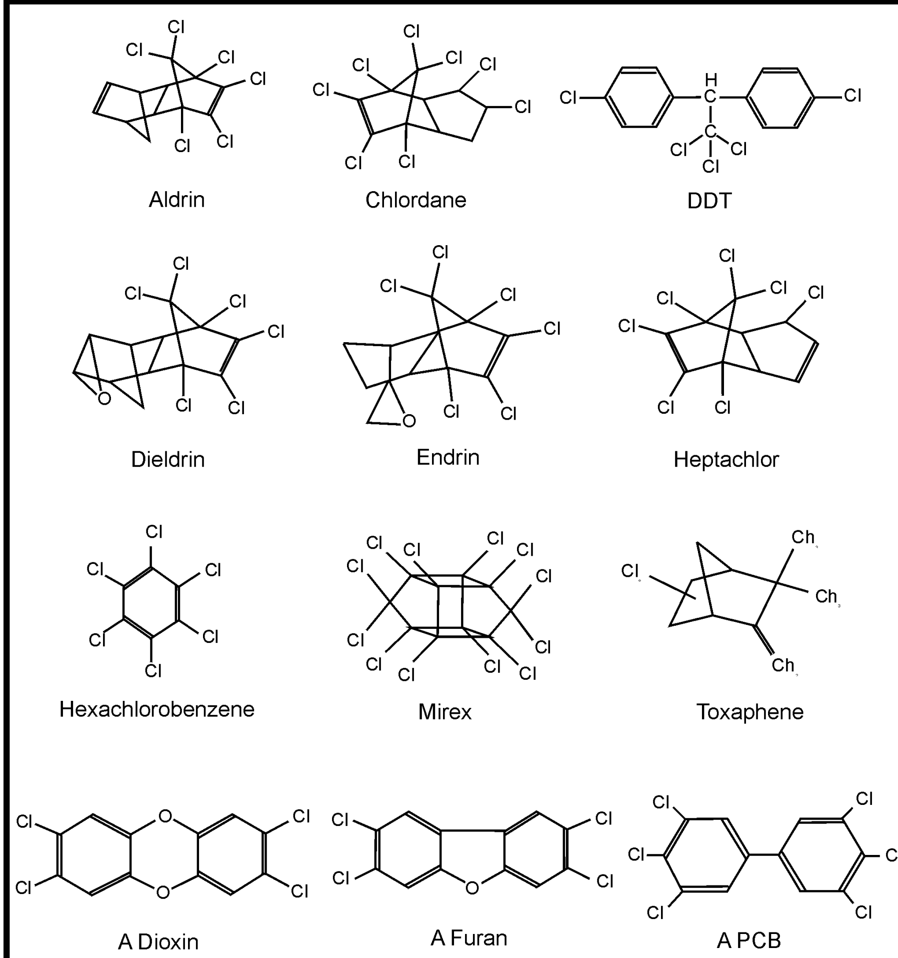
A Plethora of POPs

One of the complicating factors in dealing with the

Dioxins & Furans

"Dioxins" are a group of more than 75 different organic chemicals of a generally similar structure that includes polychlorinated dibenzo-dioxins and tetrachloro dibenzo-dioxins, while the "furans" are a closely related group of polychlorinated dibenzo-furans. They are toxic at low levels. In both groups the chlorine atoms can be located at eight different places on the molecule, and their properties and toxicities depend on the number of chlorine atoms and exactly where they are attached. Some types of dioxins and furans are produced during combustion and thus have always been naturally present in the environment as a result of forest fires. However, the amounts synthesized and released by humans far overshadow any natural contributions.

many different POP's is that most of them can occur in a bewildering variety of slightly different forms because of the subtle complexities in the architecture of hydrocarbon molecules. Sometimes, even when they have the identical chemical formula with the exact same number of different atoms in their structure, molecules can exist in a number of slightly different forms, called "isomers", depending on how and at what angle the individual atoms are bonded. Individual isomers may have very different chemical properties. POP's may also exist in a range of similar forms called "congeners", whose chemical formulas are slightly different but whose basic structure and chemical properties are sufficiently similar to warrant grouping them together. Thus dioxins, furans and PCBs are not single chemical compounds but mixtures of dozens of different isomers and congeners, each with different chemical characteristics and markedly different biological effects. For example, there are



POP s - The “Dirty Dozen”

more than 200 possible congeners encompassed by the seemingly simple acronym PCBs. Given this incredible molecular complexity, it is understandable that measuring the concentrations and analyzing the chemical composition of such complex mixtures is a highly skilled, time-consuming and very expensive process. Monitoring their distributions and movements in the environment and assessing their effects on living organisms are even more daunting tasks.

In addition, most of the pesticides sold commercially and dispersed into the environment are not pure compounds. They contain varying amounts of so-called "inert ingredients" designed to make the product mix better, spray easier, last longer on the shelf, smell better, etc. Furthermore, even the principal "active ingredient" typically consists of a variable mixture of closely related isomers and congeners, largely because of the difficulty and expense of purifying large quantities of the material. For example, "aldrin" is the ISO common name for the commercial insecticide that has at least 95% of the pure active compound, which is HHDN (hexachloro-hexahydro-dimethanonaphthalene). In addition, chemical companies frequently use a registered trademark or "brand name" in marketing their own particular formulation of a commercial pesticide, whose specific composition may change from time to time and is proprietary information. Understandably, it is virtually impossible to fully assess the biological safety of such complex mixtures.

The Dirty Dozen

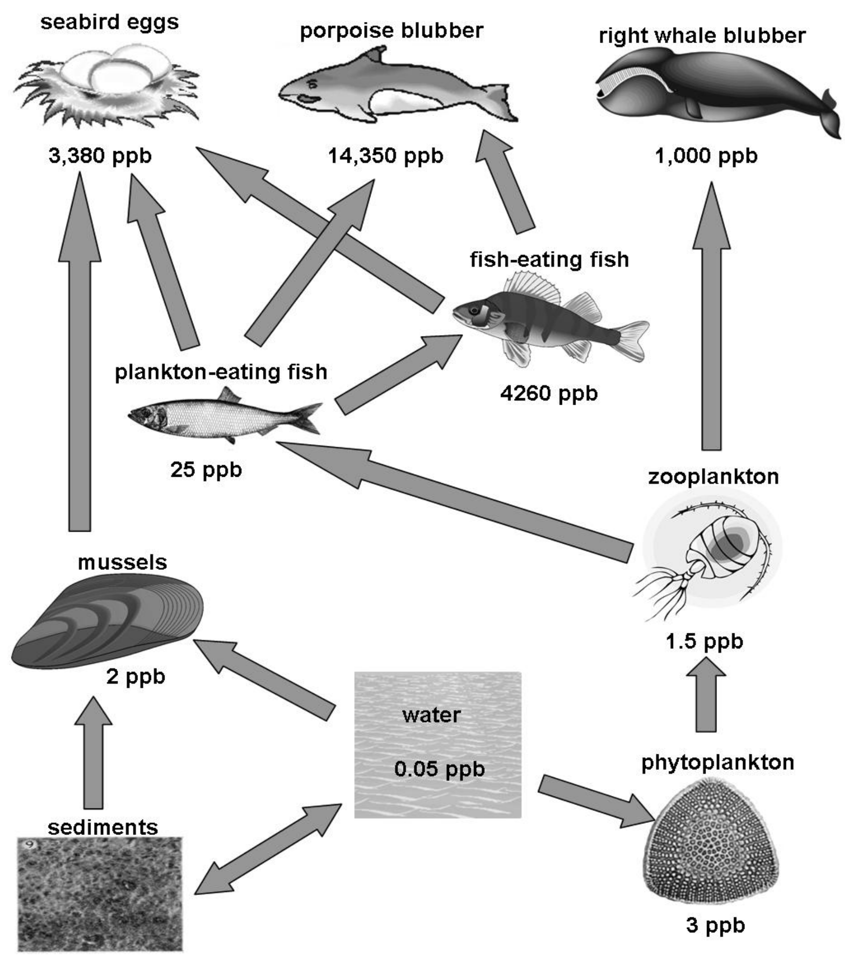
In a report released in 2000, Canada's *National Programme of Action for the Protection of the Marine Environment from Land-Based Activities* (NPA) ranked POPs as a "high priority contaminant" for the nation. This assessment is based on evidence that health of marine life and people is being adversely affected by POPs, that they are widespread in all regions of Canada, and that they are difficult and very costly to remove from the many industrial sites already contaminated. The NPA report is a little more optimistic in assessing POPs as only a "medium priority contaminant" in the Atlantic Region, noting that many major local inputs are being steadily reduced as a result of stricter regulation, although airborne transport from elsewhere is still a significant factor and PCBs contaminate the Sydney Tar Ponds in Cape Breton.

Far too many different POPs are being released into the environment to be able to conduct meaningful studies on the biological effects and regulate the inputs of most of them. The UNEP *"International Negotiating Committee on POPs"* has tried to narrow the field to a more manageable number by identifying a "dirty dozen" *(see figure),* widespread chemicals that may pose the gravest threats to ecosystems and human health. The list includes several common pesticides such as aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, mirex and toxaphene; chemicals used industrially such as hexachlorabenzene, and PCBs; and unintended byproducts such as dioxins and furans. Unfortunately, this initial list is rapidly being overtaken by the constant discoveries of new persistent industrial compounds in the environment.

Fundy Findings

Shellfish, seabirds and marine mammals are often used as convenient indicators of the amounts of chemical contaminants and pollutants present in their environment. The concentrations of various POPs have been measured periodically in habitats and tissues of several such species in the Gulf of Maine and Bay of Fundy. Shellfish, such as mussels, filter contaminated particles and absorb the chemicals from seawater. Seabirds, seals and porpoises, are long-lived, range over a wide area and feed high on the food chain. They accumulate contaminants from their prey by a process of biomagnification, whereby concentrations of contaminants steadily build up in each successive layer of the food chain. There is reliable information about the general trends in concentrations of many POPs in the Fundy region from the 1960s and early 70s to the present. This is largely attributable to the foresight of Department of Fisheries and Oceans and Environment Canada scientists in establishing long-term shellfish and seabird monitoring programs, and of some university researchers in measuring contaminants in tissues of various marine mammals over many years.

Sediments and shellfish - Measurements on samples of sediments collected at many different places reveal that many POPs, including pesticides, PCBs and PAHs, are present in the environment throughout the Gulf of Maine and Bay of Fundy. Generally, the concentrations are higher nearer to the coast than further offshore and tend to be significantly elevated near large cities and industrialized areas and are therefore much higher in the southern Gulf than in northern areas and the Bay of Fundy. A similar north-south gradient is also evident in the results of the ongoing Gulfwatch Program which periodically measures selected contaminants in a sentinel organism, the blue mussel, collected from specific sites all around the Gulf of Maine. Gulfwatch is described in more detail in Fundy Issue #12: *"Gulfwatch: Putting a Little Mussel in Gulf of Maine Monitoring"*. The Gulfwatch results indicate that the amounts of the principal types of POPs are mostly below Canadian and U.S. guidelines intended to protect wildlife populations and human health. Exceptions include areas near large industrial centres or major ports and for a period in areas around a large oil spill. The Gulfwatch database does not extend back to the 1950s and 60s, the time of peak production and release of many POPs, nor does it yet cover a long enough period to clearly demonstrate whether the concentrations of contaminants are now declining. It does, however, provide a comprehensive quantitative snapshot of present contaminant levels against which future changes can be measured.



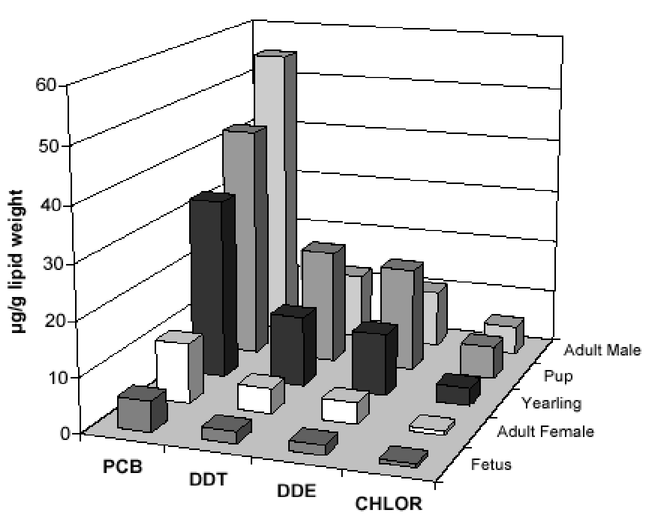
Biomagnification of PCBs in the Fundy food web
[ppb = parts per billion]
[Based on Wells et al. 1997 and G.C.H. Harding, pers. comm.]

Seabirds - One of the first real warnings that chlorinated pesticides were having a devastating effect within ecosystems were reports in the 1950s and 60s, summarized in Rachel Carson's *Silent Spring*, that large numbers of birds were dying in pesticide treated areas. In addition, some species, particularly raptors at the top of the food chain such as hawks and eagles, weren't reproducing because the developing embryos were dying or the eggshells were so thin that they broke too easily. Female birds transfer a large portion of their lipids, along with any contaminants present in them, to their forming eggs. This makes bird eggs a standard, easily sampled indicator of relative concentrations of POPs and other pollutants in the surrounding environment.

In 1968, Environment Canada began monitoring several contaminants, including POPs, in the eggs of a number of species of seabirds collected periodically from colonies around the Maritimes. The amounts of POPs found in different species usually varied with their diet and level in the food chain. For example, gannets and cormorants that eat fish (herring, mackerel etc.) had higher concentrations than terns that feed on zooplankton. An exception was an elevated level of several POPs in plankton-eating storm petrels. This may be because they often feed at the sea surface where lipophilic contaminants accumulate in the very thin, naturally oily surface film. This ongoing sampling and analysis of seabird eggs in eastern Canadian waters over five decades clearly showed the geographic distribution of contaminants, their high and often toxic concentrations in some species in the 60's and early 70s, and their gradual decline as some chemicals, such as DDT and PCBs, were banned and the production and use of others were better regulated.

Typically, organochlorine levels were highest in eggs from colonies around the Gulf of St. Lawrence, downstream from the major industrial centres of the continent, intermediate in those from the Bay of Fundy region, and lowest in eggs from coastal Newfoundland and Labrador. The concentrations of many POPs, such as DDT, DDE and PCBs declined markedly in bird eggs in the Fundy region during the late 1970s and 80's, eventually reaching levels that stubbornly persist to this day, despite the bans and other restrictions on their use. This undoubtedly reflects an ongoing slow release of contaminants deposited in sediments as well as ones leaching from old landfill sites, in addition to the long-range atmospheric and biological transport of contaminants into the region. Other organochlorines, such as dieldrin and hexachlorobenzene, have not decreased significantly, while toxaphene has even increased. However, many scientists are confident that the amounts of POPs still present in seabirds and their eggs pose no immediate threat to their health and survival.

Marine mammals - In the early 70's, the late David Gaskin and his students from the University of Guelph collected blubber samples from harbour seals from Boothbay Harbor, Grand Manan and Deer Island. They analyzed these for chlorinated pesticides and PCBs. PCB levels were particularly high, ranging from 32 to 240 parts per million. However, female seals had only about a fifth of the POPs present in males, probably because of transfer to the pups, which had elevated levels. More recent studies on seals in the region reveal that while the levels of DDT (and its breakdown products DDE and DDD) have declined significantly since the 1970s, PCB levels have decreased only slightly. PCBs, DDT and chlordane presently account for 95% of the POPs measured, while mirex, HCHs and dieldrin are present at much lower levels and aldrin, endrins and methoxychlor are not detectable. The concentrations of PCBs still present in the seals are sufficient to raise concerns about possible effects on their reproduction or on their endocrine and immune systems.



Concentrations of selected POPs in Harbour Seals of different ages in the northwestern Atlantic. (From Shaw *et al.* 2005)

Gaskin and his students also looked at organochlorine pesticides and PCBs in 60 harbour porpoises collected in 1969-70 in the Fundy region. The DDT levels were much higher than in the seals. In fact, the concentration measured in males was the highest then reported for any wild marine mammal. Since DDT use in the region had been curtailed in 1967, the researchers decided to continue sampling for several more years to see if they could detect evidence of a decline in the contaminant present in the tissues. Between 1969 and 1973 the DDT levels in tissue went "down very remarkably". However, between 1974 and 1977 the average concentration rose almost to the earlier maximum. It may be that significant amounts of DDT were being resuspended from bottom sediments. DDT levels subsequently decreased again and there has been an overall decline from the 1970s to the 1990s. Early on, PCB levels in the porpoises were also high, particularly in the blubber. Between 1971 and 1977 there was no evidence of any decline in the concentration. By the mid 1990s, PCBs still formed the bulk of the POPs present in porpoise tissue. The persisting high levels in both seals and porpoises clearly warrants a closer look at possible effects on their health, especially as the PCBs are unlikely to decrease significantly for some time because of chronic inputs from industrial and municipal dumpsites.

Many endangered North Atlantic Right Whales summer near the mouth of the Bay of Fundy. Part of the recovery plan for the species involves measuring contaminants in their tissues in order to evaluate possible health implications. The most comprehensive sampling program was carried out in the late 1980s. Small plugs of blubber were collected for analysis by means of a small, retrievable, harpoon-like, sampling tube fired from a modified crossbow. While many organochlorines were present in the blubber, their overall levels were much lower than that in the smaller marine mammals, such as seals and porpoises. This may be because these large whales feed low on the food chain on plankton and are thus less subject to biomagnification effects. Mature females had lower levels than the rest of the population, likely reflecting a transfer of contaminants to the young during embryonic development or with the milk during suckling. Of all the organochlorines measured, PCBs were in the highest concentration, followed by DDT and its breakdown products. However, the concentrations appeared to be below the levels that are thought to impair the health of marine mammals such as seals and porpoises.

POPs in the peat - Clearly, many of the POPs in Fundy's coastal waters have decreased markedly over the past three or four decades. Recent studies in peat bogs in eastern North America and around the Bay of Fundy have provided a complementary record of the rise and fall in concentrations of POPs in the region similar to that observed in shellfish, seabirds and marine mammals. Peat bogs result from a steady build up of layers of dead organic matter beneath the living mossy surface. Cores of peat extracted from undisturbed bogs contain along their length a continuous record of the many compounds deposited from the atmosphere over decades or even centuries. Researchers have shown that the history of the manufacture and sales of several POPs is closely mirrored by the amounts found at different depths in the bog. For example, hexachlorobenzene, which entered commercial production in 1915, first appears at the depth corresponding to that date, then the concentration increases steadily to a peak in 1967 when its use began to be greatly reduced. Subsequently, the concentration in the cores declined sharply to the lower constant level that persists to this day.

Curbing the Contaminants

The inputs of POPs into the environment rose dramatically after the Second World War and continued into the 1950s and 60s. Little thought was given to the consequences of this widespread dispersal for other species in the natural ecosystem or for human health. However, the mounting scientific evidence of a developing ecological catastrophe was skillfully synthesized by Rachel Carson and courageously brought to the attention of the world in her book *Silent Spring*. The resulting public outcry led to increasing curbs on the use of pesticides and other persistent organic pollutants. More stringent regulations along with better monitoring and enforcement have reduced the amounts of toxic compounds released from industrial smokestacks and factory outfalls. Many industries now recognize that reducing their chemical wastes is often economically, as well as environmentally, beneficial. Nevertheless, there is still room for improvement, particularly with regard to the dozens of new POPs being created in labs and commercially produced every year, and increasing inputs from new sources such as commercial aquaculture.

Environment Canada must continue to gather data about the quantities of POPs and other chemicals being released into the environment by individual industrial plants and other economic operations such as forestry, mining and farming, and to make this information publicly accessible via the *National Pollutant Release Inventory*. This not only provides industry with a yardstick to measure, and an incentive to make, progress in reducing contaminants, but also spotlights significant problem areas still remaining. As contaminant removal technology improves, new manufacturing procedures are developed and lower toxicity materials become available, the regulations under the *Canadian Environmental Protection Act*, the *Fisheries Act*, and the *Pest Control Products Act* need to be regularly revised accordingly. This may involve periodically tightening the national standards for permitted release of toxic substances and strengthening the codes of practice for different industrial sectors.

There should also be a continuation of the research to better understand the biological effects of POP's as well as a comprehensive program to determine the toxicity of newly developed POPs before they are approved for commercial use. More field studies are needed to determine whether the levels of POPs now present in the marine environment are affecting plant and animal populations. This is particularly true for endocrine disrupting compounds that may be insidiously affecting reproduction and development of marine organisms. We also need to continue monitoring trends in the concentrations of selected POPs in the marine environment and in key indicator species from all around the Gulf of Maine. This will indicate the effectiveness of regulatory programs designed to reduce inputs and also detect emerging threats. The Gulfwatch Program has already demonstrated the benefits of such a long-term, geographically broad approach to monitoring.

"Everyone who lives in the Bay of Fundy and Gulf of Maine watersheds has an important role to play in protecting our coastal ecosystems, and ourselves, from the scourge of toxic POPs."

POPs can travel great distances with atmospheric and oceanic circulation and biological transport, and degrade ecosystems far from their point of origin. Much of the POPs now present in the Fundy watershed comes from the distant industrial heartland of North America and even farther afield. Therefore, provincial and federal governments must continue to actively negotiate regional, national and international agreements to reduce the amounts of POPs released into the global environment. UNEP, the United Nations Environmental Programme, is already working towards developing an international consensus on regulating many toxic chemicals. *The Stockholm Convention on Persistent Organic Pollutants POPs*, adopted in 2001, "seeks the elimination or restriction of production and use of all intentionally produced POPs (*i.e.* industrial chemicals and pesticides) and, when feasible, ultimate elimination of releases of unintentionally produced POPs such as dioxins and furans". The Convention also requires that "stockpiles must be managed and disposed of in a safe and environmentally sound manner". The eventual goal is the elimination of the use of the pesticides aldrin, chlordane, dieldrin, endrin, heptachlor, hexachlobenzene, mirex and toxaphene. The use of PCBs by industry will also be discontinued. However, DDT may continue to be used in certain countries to kill disease-carrying insects until a safer, cost effective control method is found. *The Stockholm Convention* builds upon earlier treaties on the management of hazardous chemicals, particularly the 1989 *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal* and the 1998 *Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade*. This suite of UNEP Conventions forms an international framework for "lifecycle" or "cradle to grave" management of the major types of hazardous compounds, particularly POPs, by implementing such management concepts of *"Best Available Techniques"* and *"Best Environmental Practices"*.

Many nations, including Canada, have already ratified these conventions. However, the difficulties and challenges associated with destroying the remaining stockpiles of various POPs, enforcing the more rigorous regulations, monitoring older POPs still in the environment, and the continuing production of new types of POPs means that toxic chemicals will be an ongoing environmental issue. In addition, new studies revealing more and more insidious sublethal effects of these compounds on marine organisms and humans adds even greater urgency to international efforts to control their release into the environment.

However, we cannot rely solely on government agencies, international conventions or more stringent regulation of industrial inputs to eliminate the threat from POPs. Many industries have significantly reduced their emissions in recent decades and continue to seek less problematic chemicals for manufacturing processes. Ironically, the relative proportion contributed by non-commercial and domestic sources has been steadily rising because expanding urban populations, a broadening range of household and garden products containing hazardous compounds, coupled with inadequate regulation of their use and disposal, have made the general public collectively a significant polluter. We need to educate ourselves about the dangers of indiscriminately spreading toxic chemicals on our properties and thoughtlessly flushing leftover chemical wastes and potent cleaning agents down our drains. We need to be more aware of the need for proper and safe storage, handling, mixing, application and disposal of the toxic chemicals that are so readily available over the counter at local hardware stores and garden centres. We particularly need to read and heed the informative warning labels that government regulations require on all such hazardous products. Everyone who lives in the Bay of Fundy and Gulf of Maine watersheds has an important role to play in protecting our coastal ecosystems, and ourselves, from the worrisome scourge of toxic POPs.

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Fundy Issues are also available on the BoFEP Website at: **http://www.bofep.org**

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