# Human Health

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# Section 6: Human Health

*(This section presents a preliminary summary of the work of the Lake Erie LaMP Human Health Subcommittee to date. The subcommittee has drafted a detailed background document to assess the threat to human health from critical pollutants and other contaminants of concern in Lake Erie, but it has not yet undergone a comprehensive LaMP review.)*

## 6.1 Introduction

There is concern about the effects that Great Lakes' contaminants and, in particular, persistent, bioaccumulative toxic chemicals, may have on human health. The 1987 Protocol to the Great Lakes Water Quality Agreement of 1978 (GLWQA) states that Lakewide Management Plans (LaMPs) for open lake waters shall include: "A definition of the threat to human health or aquatic life posed by Critical Pollutants, singly or in synergistic or additive combination with another substance, including their contribution to the impairment of beneficial uses." Critical pollutants are those persistent bioaccumulative toxic chemicals that have caused, or are likely to cause, impairments of the beneficial uses of each Great Lake. Three of these beneficial uses (fish consumption, drinking water consumption and recreational water use) are directly related to human health. The goal of this Lake Erie LaMP 2000 section is to fulfill the human health requirements of the GLWQA, including:

- to define the threat to human health and describe the potential adverse human health effects arising from exposure to critical pollutants and other contaminants (including microbial contaminants) found in the Lake Erie basin;
- to address current and emerging human health issues of relevance to the LaMP but not currently addressed in the other components of the LaMP; and
- to identify implementation strategies currently being undertaken to protect human health and suggest additional implementation strategies that would enhance the protection of human health.

In defining the threat to human health from exposure to the Lake Erie LaMP critical pollutants, (PCBs and mercury) and the other Lake Erie LaMP pollutants of concern (Table 5.2), this assessment applies a weight of evidence approach, which uses the overall evidence from wildlife studies, experimental animal studies, and human studies in combination. In addition to examining the chemical pollutants of concern to human health for Lake Erie, this section also examines microbial pollutants in recreational and drinking water.

The World Health Organization defines human health as a "state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (World Health Organization, 1984). Therefore, when assessing human health, all aspects of well-being need to be considered, including physical, social, emotional, spiritual and environmental impacts on health. Human health is influenced by a range of factors, such as the physical environment (including environmental contaminants), heredity, lifestyle (smoking, drinking, diet and exercise), occupation, the social and economic environment the person lives in, or combinations of these factors. Exposure to environmental contaminants is one among many factors that contribute to the state of our health (Health Canada, 1997).

Consideration of human health in the Lake Erie basin must also take into account the diversity of the Lake Erie basin population, which includes a range of ethnic and socioeconomic groups. Certain subpopulations, such as high fish consumers, may have higher exposures to persistent toxic chemicals than the general population. In addition, some subpopulations, such as the elderly, immunologically compromised, women of child-bearing age, the fetus, nursing infants, and children may be more susceptible to the effects of persistent bioaccumulative toxic chemicals (Johnson *et al.*,, 1998; Health Canada, 1998d).

Therefore, the discussion of health issues in this section looks at the health of the general population as well as subpopulations at increased risk of exposure and health effects.

Section 6.2 describes the pathways of exposure relevant to human health - drinking water, recreational water use and fish/food consumption. Section 6.3 explains and applies a weight of evidence approach to looking at potential health effects. Section 6.4 describes proposed indicators of human health for Lake Erie. Conclusions and recommended actions to be taken to protect human health are presented in Section 6.5. References are listed in Section 6.6. A list of Lake Erie relevant human health Internet resources and additional references is included in Appendix H.

## 6.2 Pathways of Exposure and Human Health

The three major routes through which chemical and microbial pollutants enter the human body are by ingestion (water, food, soil), inhalation (airborne), and dermal contact (skin exposure). The goal of the Lake Erie LaMP is "to restore and protect the beneficial uses of Lake Erie, such as safe beaches, clean drinking water and healthy fish and wildlife populations" (Lake Erie LaMP Status Report, 1999). Awareness of the underlying causes of these restrictions (e.g. chemical and microbial contaminants) and the associated health consequences will allow public health agencies to develop societal responses protective of public health. Desired outcomes for human health and the exposure pathways they relate to are identified in Table 6.1.

### Table 6.1: Human Health-Related Desired Outcomes, and Pathways of Exposure



| Desired Outcomes | Pathway of Exposure |
|---|---|
| Fishable - We can all eat any fish | Ingestion of food (fish) |
| Drinkable - Treated drinking water is safe for human consumption; We can all drink the water | Ingestion of water |
| Swimmable - All beaches are open and available for public swimming; We can all swim in the water | Incidental ingestion of water, dermal contact, inhalation of water spray from splashing, etc. |

The scope of the Lake Erie LaMP includes pathways of exposure through the water. Therefore, air pollution is not discussed in this human health paper. Nonetheless, air pollution as it relates to the air we breathe is a key health issue for the Lake Erie basin, and programs and initiatives are in place in both the U.S. and Canada that address this issue. For the United States, the Clean Air Act, implemented by the U.S. EPA and state agencies, is primarily responsible for ensuring the quality of ambient air by regulating point and mobile source emissions to the environment (for more information refer to http://www.epa.gov/oar/oarhome.html). The Occupational Safety and Health Administration implements the Occupational Safety and Health Act which protects health in the workplace - including health related to air quality (for more information refer to http://www.osha.gov).

In Canada, Health Canada conducts air pollution health effects research, risk assessments and exposure guidelines creation through the Air Pollution Health Effects Research Program in its Environmental Health Directorate (http://www.hc-sc.gc.ca/ehp/ehd/bch/air_quality.htm). The Province of Ontario also has programs targeted at the protection of humans from exposure to air pollution.

The critical pollutants and chemical pollutants of concern in Lake Erie include organochlorines and metals that are known to cause adverse health effects in animals and humans. These chemicals do not break down easily, persist in the environment, and bioaccumulate in aquatic biota, animal and human tissue; thus they are called *persistent bioaccumulative toxic* chemicals (PBTs). Organochlorines tend to accumulate in fat (such as adipose tissue and breast milk), and metals tend to accumulate in organs, muscle and flesh. Food is the primary route of human exposure to these PBT chemicals, and consumption of Great Lakes' fish is the most important source of exposure originating directly from the lakes. Sources from air, soil/dust, and water constitute a minor route of exposure (Health

Canada, 1998e; Johnson *et al.*,, 1998).

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin, leading to declines in levels in human tissue, for example, lead in blood and organochlorine contaminants in breast milk. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern in the Lake Erie basin. Although contaminant levels in the Great Lakes are declining in general, recent trends suggest that concentrations for some pollutants may be leveling off. However, health concerns from environmental contaminant exposures in the Lake Erie basin remain. Therefore, public health advisories and other guidelines should be followed to minimize contaminant exposures. Most of the health effects studies for Great Lakes PBT chemicals have focused on fish consumption.

Access to clean drinking water is essential to good health. The waters of Lake Erie and surrounding areas are a primary source of drinking water for people who live in the Lake Erie basin. The average adult drinks about 1.5 liters of water a day, so health effects could be serious if high levels of some contaminants are present (Health Canada, 1993, 1997).

A variety of contaminants can adversely affect drinking water, including micro-organisms (e.g. bacteria, viruses and protozoa, such as *cryptosporidium*), chemical contaminants (both naturally occurring, synthetic and anthropogenic), and radiological contaminants, including naturally-occurring inorganic and radioactive materials (IJC, 1996; Health Canada, 1997; Lake Erie LaMP, 1999; OME, 1999). Some contaminants in raw water supplies, such as aluminum, arsenic, copper and lead, can be both naturally occurring and resulting from human activities. Other contaminants, such as household chemicals, industrial products, fertilizers (including nitrates), human and animal wastes, and pesticides may also end up in raw water supplies (U.S. EPA, 1999a; Health Canada, 1998b).

Microbial contamination of drinking water can pose a potential public health risk in terms of acute outbreaks of disease. The illnesses associated with contaminated drinking water are mainly gastro-intestinal in nature, although some pathogens are capable of causing severe and life-threatening illness (Health Canada, 1995b). In most communities, drinking water is treated to remove contaminants before being piped to consumers, and bacterial contamination of municipal water supplies has been largely eliminated by adding chlorine or other disinfectants to drinking water to prevent waterborne disease. By treating drinking water and wastewater, diseases such as typhoid and cholera have been virtually eliminated. Although other disinfectants are available, chlorination still tends to be the treatment of choice. When used with multiple barrier systems (i.e. coagulation, flocculation, sedimentation and/or filtration), chlorine is effective against virtually all infective agents (U.S. EPA/Government of Canada, 1995; Health Canada, 1993, 1997, 1998f).

The Great Lakes are an important resource for recreation, including activities such as swimming, water-skiing, sail-boarding and wading that involve body contact with the water. Apart from the risks of accidental injuries, the major human health concern for recreational waters is microbial contamination by bacteria, viruses, and protozoa (Health Canada, 1998a; WHO, 1998). Many sources or conditions can contribute to microbiological contamination, including sewer overflows after heavy rains (Whitman *et al.*,, 1995). On-shore winds can stir up sediment or sweep bacteria in from contaminated areas. Animal/pet waste may be deposited on the beach or washed into storm sewers. Agricultural runoff, such as manure, is another source. Stormwater runoff in rural and wilderness area watersheds can increase densities of fecal streptococci and fecal coliforms as well (Whitman *et al.*,, 1995). Other contaminant sources include infected bathers/swimmers; direct discharges of sewage from recreational vessels; and malfunctioning private systems (e.g. cottages, resorts) (Health Canada, 1998a, Whitman *et al.*, 1995; WHO, 1998).

Human exposure to micro-organisms occurs primarily through ingestion of water, and can also occur via the entry of water through the ears, eyes, nose, broken skin, and through contact with the skin. Gastro-intestinal disorders, respiratory illness and minor skin, eye, ear, nose and throat infections have been associated with microbial contamination of recreational waters (Health Canada, 1998a; WHO, 1998; Prüss, 1998).

Studies have shown that swimmers and people engaging in other recreational water sports have a higher incidence of symptomatic illnesses such as gastroenteritis, otitis, skin infection, and conjunctivitis, and acute febrile respiratory illness (AFRI) following activities in recreational waters (Dewailly, 1996; WHO, 1998). Although current studies are not sufficiently validated to allow calculation of risk levels (Health Canada, 1992), there is some evidence that swimmers/bathers tend to be at a significantly elevated risk of contracting certain illnesses (most frequently upper respiratory or gastro-intestinal illness) compared with people who do not enter the water (Dufour, 1984; Seyfried *et al.*,, 1985a, b; U.S. EPA, 1986; WHO, 1998; Prüss, 1998). In addition, children, the elderly, and people with weakened immune systems are those most likely to develop illnesses or infections after swimming in polluted water (Health Canada, 1998a).

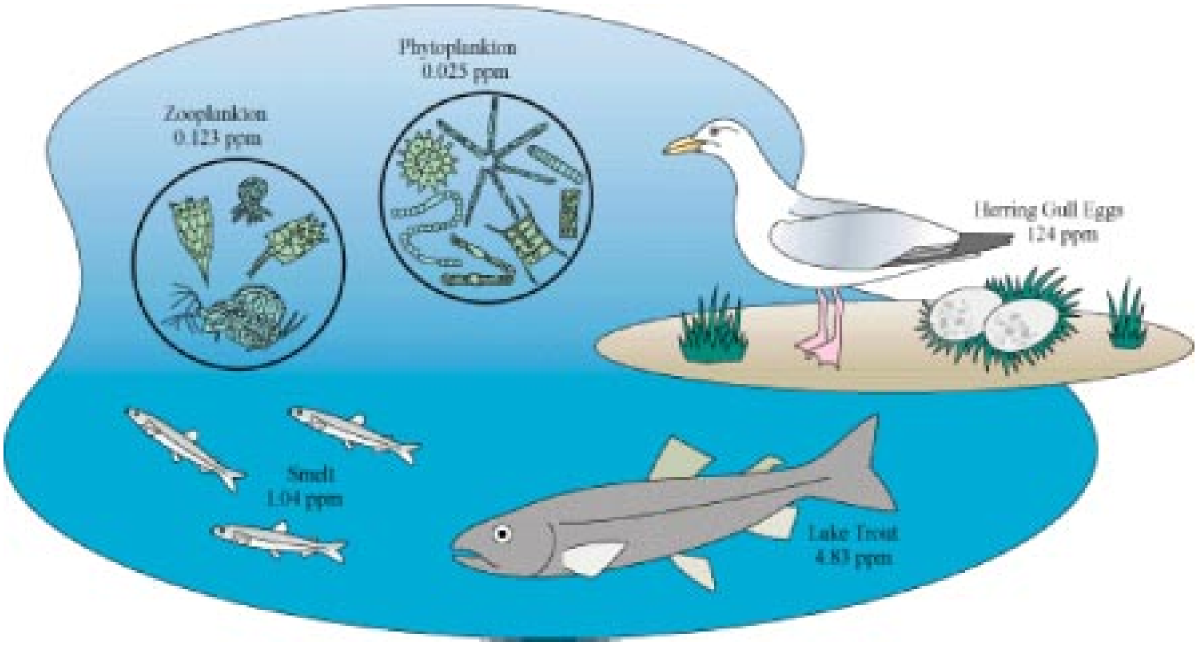
Chemical contaminants such as PAHs have been identified as a possible concern for dermal (skin) exposure in recreational waters. Dermal exposure may occur when people come into contact with contaminated sediment or contaminated suspended sediment particulates in the water. PAHs adsorbed to these particulates would adhere to the skin. There is little information available regarding chemical contaminants with the potential to cause effects such as skin rashes, or how much of a chemical might be absorbed through the skin, with the potential to cause systemic effects, such as cancer (Hussain *et al.*, 1998; Lake Erie LaMP, 1999).

Exposure assessments from all sources (air, water, food and soil) were completed for the Canadian Great Lakes basin general population for 11 PBT chemicals, including PCBs and mercury. The total estimated daily intake averaged over a lifetime was well below the Tolerable Daily Intake (TDI) established by Health Canada (Health Canada, 1998c). Consequently, the approach by various agencies has been to examine groups at higher risk of exposure to PBT chemicals from Great Lakes' sources, such as high consumers of sport fish.

Fish are low in fat, high in protein, and may have substantial health benefits when eaten in place of high-fat foods. However, chemicals such as mercury and PCBs enter the aquatic environment and build up in the food chain. The levels of the chemicals in fish from the Lake Erie basin are generally low and do not cause acute illness. Continued low level exposure to these chemicals, however, may result in adverse human health effects. People need to be aware of the presence of contaminants in sport fish and, in some cases, take action to reduce exposure to chemicals while still enjoying the benefits of catching and eating fish.

Contaminants usually persist in surface waters at very low concentrations. They can bioaccumulate in aquatic organisms and become concentrated at levels that are much higher than in the water column. This is especially true for substances that do not break down readily in the environment, like the Lake Erie LaMP critical pollutants PCBs and mercury. As contaminants bioaccumulate in aquatic organisms, this effect biomagnifies with each level of the food chain. As a result of this effect, the concentration of contaminants in the tissues of top predators, such as lake trout and large salmon, can be millions of times higher than the concentration in the water. Figure 6.1 illustrates an example of the changes in PCB concentration (in parts per million, ppm) at each level of a Great Lakes aquatic food chain. The highest levels are reached in the eggs of fish-eating birds such as herring gulls.

**Figure 6.1: Persistent Organic Chemicals Such as PCBs Bioaccumulate and Biomagnify as They Move Up the Food Chain**






*This diagram shows the degree of concentration in each level of the Great Lakes aquatic food chain for PCBs (in parts per million, ppm). The highest levels are reached in the eggs of fish-eating birds such as herring gulls.*

Text and figure from *The Great Lakes: An Environmental Atlas and Resource Book* Government of Canada/U.S. EPA, 1995

## 6.3 Evidence for Potential Health Effects - Weight of Evidence Approach to Linking Environmental Exposure

*(Due to the importance of using a weight of evidence approach in assessing human health impacts, this section represents most of the information included in the draft background report prepared by the Human Health Subcommittee.)*

The following three subsections describe selected studies that have reported associations between PBT chemical exposures and effects in wildlife, laboratory animals and human populations. Because of the ethical issue of exposing humans to toxic substances and factors such as a small sample size and presence of multiple chemicals, human studies are often limited in their ability to establish a causal relationship between exposure to chemicals and potential adverse human health effects. In addition, human studies looking at causal relationships between human exposure to environmental contaminants and adverse health outcomes are limited and the results uncertain. Therefore, a weight of evidence approach is used, where the overall evidence from wildlife studies, experimental animal studies, and human studies is considered in combination. It utilizes the available information from wildlife and controlled animal experiments to supplement the results of human studies toward assessing the risks to human health from exposure to PBT chemicals. The use of wildlife data assumes that animals can act as sentinels for adverse effects observed in humans (Johnson and Jones 1992).

### 6.3.1 Wildlife Populations

Research over the past 25 years has shown that a variety of persistent, bioaccumulative contaminants in the Great Lakes food chain are toxic to wildlife (Health Canada, 1997). Reproductive impairments have been described in avian, fish, and mammalian populations in the Great Lakes. For example, egg loss due to eggshell thinning has been observed in predatory birds, such as the bald eagle, within the Great Lakes (Menzer and Nelson, 1980). After feeding on Great Lakes' fish for two or more years, immigrant birds (eagles) were shown to have a decline in reproductive success (Colburn *et al.*,, 1993). Developmental effects in the form of congenital deformities (e.g. crossed mandibles, club feet) have also been reported in the avian population within the Great Lakes basin (Stone, 1992).

Effects to the endocrine system and tumor formations have been detected in fish populations. Researchers have reported enlarged thyroids in all of the 2 to 4 year-old Great Lakes salmon stocks that were examined (Leatherland, 1992). Tumors associated with exposure to high levels of PAHs have been detected in brown bullhead in the Great Lakes area (Baumann *et al.*,, 1982).

Effects on the immune system have also been a notable finding. At a number of Great Lakes sites, a survey of herring gulls and Caspian terns demonstrated a suppression of T-cell-mediated immunity following prenatal exposure to organochlorine pollutants particularly PCBs (Grasman *et al.*,, 1996). Section 4 provides a more detailed description of the effects of chemicals on wildlife, but the point here is to show that adverse effects can occur when exposure is sufficient (Health Canada, 1997).

### 6.3.2 Animal Experiments

A number of animal experiments have demonstrated a wide range of health outcomes from exposure to PCBs, mercury and chlorinated dibenzo-p-dioxins (CDD).



*PCBs (polychlorinated biphenyls)*: Animals exposed orally to PCBs developed effects to the hepatic, immunological, neurological, developmental and reproductive systems. Effects have also been reported in the gastrointestinal and hematological systems (ATSDR 1998). Animal ingestion studies strongly support the finding that more highly chlorinated PCBs (i.e., 60% chlorine by weight) are carcinogenic to the livers of rats, while the lower chlorinated PCBs are weaker animal carcinogens (i.e. lower incidence of total tumors and more benign tumors)
(Buchmann *et al.*,, 1991; Sargent *et al.*,, 1992).

*Mercury*: Long-term, high level animal ingestion exposure to mercury has been associated with cardiovascular (Arito and Takahashi, 1991), developmental (Fuyuta *et al.*,, 1978; Nolen *et al.*,, 1972; Inouye *et al.*,,1985), gastrointestinal (Mitsumori *et al.*,, 1990), immune (Ilback, 1991), renal (Yasutake *et al.*,, 1991; Magos *et al.*,, 1985; Magos and Butler, 1972; Fowler, 1972) and reproductive effects (Burbacher *et al.*,, 1988; Mitsumori *et al.*,, 1990; Mohamed *et al.*,, 1987). The studies also indicate that the nervous system is particularly sensitive to mercury exposure by ingestion (Fuyuta *et al.*,, 1978; Magos *et al.*,, 1980, 1985). In addition, growth of kidney tumors has been reported in animals administered methylmercury in drinking water or diet for extended periods (Mitsumori *et al.*,, 1981, 1990).

*CDDs (chlorinated dibenzo-p-dioxins)*: In specific species (e.g. guinea pig), very low levels of 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) have resulted in the death of the exposed animal after a single ingestion dose (NTP, 1982). At non-lethal levels of 2,3,7,8-TCDD by ingestion, other effects reported in animals include weight loss (NTP, 1982), biochemical and degenerative changes in the liver (NTP, 1982; Kociba *et al.*,, 1978), and a decline in blood cells (Kociba *et al.*,, 1978). Dermal effects in animals (e.g. hair loss, chloracne) have also been reported by ingestion exposure (McConnell *et al.*,, 1978). In many species, the immune system and fetal development are particularly susceptible to 2,3,7,8-TCDD exposure. Offspring of animals receiving oral exposure to 2,3,7,8-TCDD developed birth defects such as skeletal deformities and kidney defects, weakened immune responses, impaired reproductive system development, and learning and behavior impairments (Giavini *et al.*,, 1983; Gray and Ostby, 1995; Tryphonas, 1995; Schantz and Bowman, 1989; Schantz *et al.*,, 1992). Reproductive effects in the form of miscarriages were reported in rats, rabbits, and monkeys exposed orally to 2,3,7,8-TCDD during pregnancy (McNulty, 1984). Rats of both sexes were observed to have endocrine changes in the form of alterations in sex hormone levels with dietary exposure. Other reproductive effects include a decline in sperm production in male rats, and carcinogenic effects of cancer of the liver, thyroid, and other sites in rats and mice exposed orally to 2,3,7,8-TCDD (NTP, 1982; Kociba *et al.*,, 1978). Research evidence is also increasing supporting the neurotoxic effect for mammals and birds from ingestion exposure to dioxin-like compounds, including certain PCBs and CDFs. Changes in thyroid hormones and neurotransmitters, singly or together, at critical periods in the development of the fetus are considered responsible for the neurological changes (Brouwer *et al.*,, 1995; De Vito *et al.*,, 1995; Henshel *et al.*,, 1995b; Henshel and Martin, 1995a; Vo *et al.*,, 1993).

### 6.3.3 Human Health Studies

Demonstrating health effects in humans from chronic, low-level exposure to persistent organic pollutants typically encountered in the Great Lakes region is a challenge for researchers. Exposure to contaminants from Great Lakes fish is dependent upon the amount eaten and species consumed. Overall, there is limited information available on exposure levels, body burdens and health effects for people who consume Lake Erie fish. Currently, the Agency for Toxic Substances and Disease Registry (ATSDR) is funding studies investigating populations that reside in the Lake Erie basin and consume Lake Erie fish. The ATSDR studies will determine exposure and body burden levels, and potential health effects. In addition, two Health Canada fish consumption studies include participants from the Lake Erie basin. Along with results from the Lake Erie studies, research examining other Great Lakes will be used to assess risks and benefits of eating Great Lakes fish.



***Exposure Studies***

Due to the effects of bioaccumulation and biomagnification, fish consumption has been shown to be a major pathway of human exposure to PBT chemicals such as PCBs (Birmingham *et al.*,, 1989; Fitzgerald *et al.*,, 1996; Humphrey, 1983; Newhook, 1988), exceeding exposures from land, air, or water sources (Humphrey, 1988). Humphrey (1988) reported that PCBs were the dominant contaminants detected in Lake Michigan trout (3,012 parts per billion or ppb) and chinook and coho salmon (2,285 ppb), surpassing other contaminants such as DDT (1,505 ppb, 1,208 ppb), hexachlorobenzene (5 ppb, 5 ppb), oxychlordane (25 ppb, none shown), trans-nonachlor (195 ppb, 162 ppb), and dieldrin (75 ppb, 53 ppb), respectively in trout and salmon. Fish specimens collected from the dinner plate of study participants were used to determine these median PCB concentrations. Recently, total PCB levels have decreased in most Lake Michigan fish species and appear to remain below the FDA action level of 2000 ppb, but the concentrations in chinook and coho salmon have risen slightly since the late 1980s (Stow *et al.*,, 1995).

Early investigations of Lake Michigan fish consumption have broadened our knowledge about transmission of contaminants from fish to humans, including maternal exposure of the fetus and infant. Investigating a cohort of State of Michigan fish eaters, Humphrey (1988) discovered that sport anglers who regularly consumed Great Lakes salmon and trout (consumption rate of $24 pounds/year - or $11 kg/year) had median serum PCB levels approximately four times higher (56 ppb) than those who consumed no Great Lakes fish (15 ppb). PCBs have also been detected in adipose tissue, breast milk, and cord blood, and associated with consumption of contaminated fish (ATSDR, 1998). Schwartz *et al.*, (1983) demonstrated that consumption of Lake Michigan fish was positively associated with the PCB concentration in maternal serum and breast milk. Maternal serum PCB concentrations were also positively associated with the PCB levels in the umbilical cord serum of the infant (Jacobson *et al.*,, 1983).

Although the levels of PCBs have declined in most species of Lake Michigan fish, lipophilic pollutants, such as PCBs, have a tendency to bioaccumulate in the human body. Hovinga *et al.*,, (1992) reported a mean serum PCB concentration of 20.5 ppb in 1982 for persons consuming >24 pounds of Lake Michigan sport fish per year, and 19 ppb in 1989 demonstrating little decline within the 7 year interval. For those ingesting <6 pounds of Lake Michigan sport fish per year, the mean serum PCB concentrations were 6.6 ppb in 1982, and 6.8 ppb in 1989. The mean serum PCB concentrations for those consuming <6 pounds of Lake Michigan fish per year are comparable to the mean serum PCB levels of 4 to 8 ppb found in the general population who do not have occupational PCB exposure (Kreiss, 1985).

Research has shown that at risk communities for exposure to contaminants from fish consumption include Native Americans, minorities, sport anglers, elderly, pregnant women, and fetuses and infants of mothers consuming contaminated Great Lakes fish (Dellinger *et al.*,,1996, Fitzgerald *et al.*,, 1996, Lonky *et al.*,, 1996, Schantz *et al.*,, 1996). These communities may consume more fish than the general populations or have physiologic attributes, such as physical and genetic susceptibilities, that may cause them to be a greater risk. Higher body burdens of mean serum PCBs and DDE were found in an elderly cohort of Lake Michigan fish eaters (i.e. $50 years of age) who were compared to non-fish eaters (Schantz *et al.*,, 1996). Fish eaters had mean serum PCB levels of 16 ppb while the non-fish eaters had mean levels of 6 ppb. For DDE, fish eaters had mean serum levels of 16 ppb and the non-fish eaters had a mean level of 7 ppb.

Gender difference in fish consumption is an issue of interest that is being investigated, toward better identifying at-risk populations. One Michigan sport anglers study, with subjects between the ages of 18-34 years, demonstrated gender differences with males tending to consume more fish than female subjects (Courval *et al.*,, 1996). Conversely, Health Canada=s Great Lakes Fish Eaters Study (discussed below) found that women in the high fish consumption group eat more fish than men (Kearney, 2000, personal communication).



In a recent Health Canada study carried out in five areas of concern in the lower Canadian Great Lakes, 4,637 shoreline fishers were interviewed. The demographic data show that there is no such thing as *a typical* fisher. People who like to fish come from different cultural backgrounds, are different ages and have different occupations. Thirty-eight percent of the shoreline fishers interviewed reported eating at least one meal of fish during the previous 12 months. Twenty-seven percent of shoreline fishers interviewed reported eating more than 26 meals of fish in a year. As the number of fish meals consumed increased, so did the likelihood that parts of the fish other than the fillet were being consumed. Approximately one third of the fish eaters said that they used the *Guide to Eating Ontario Sport Fish* (Health Canada, 2000).

A concurrent project, the Great Lakes Fish Eaters Study (not yet released) took a more in-depth look at exposure to environmental contaminants in people eating large amounts of Great Lakes fish. Environmental contaminant levels were measured in blood samples collected from the study participants. As well, nutritional and social benefits associated with consumption of Great Lakes fish were examined (Kearney, 2000, personal communication).

In a study by Kearney *et al.*, done in 1992-93 blood levels of PCBs in men and women between Great Lakes fish eaters and non-fish eaters were compared for Mississauga and Cornwall (in the Lake Ontario basin) combined. For male fish eaters the median level was 5.5 ppb, for male non-fish eaters it was 3.9 ppb. For women fish eaters and non-fish eaters the median levels were 3.4 and 3.2 ppb, respectively. These differences were statistically significant for men only. Relative to fish eaters and families on the north shore of the St. Lawrence River (geometric mean 35.2 ppb) and Quebec Inuit (geometric mean 16.1 ppb), these values are low. Total mercury levels measured in the same participants were also low; the median levels for male Great Lakes fish eaters and non-eaters were 2.65 and 1.70 ppb, respectively. Median levels for female Great Lakes fish eaters and non-eaters were 2.10 and 1.45 ppb, respectively. Levels were generally at the lower end of the *normal acceptable range* (< 20 ppb) as defined by the Medical Services Branch of Health Canada and based on WHO guidelines.

Hanrahan *et al.,* (1999) corroborated previous findings relating frequent Great Lakes sport fish consumption to a higher body burden for PCBs and DDE. The study examined relationships between demographic characteristics, Great Lakes sport fish consumption, PCB, and DDE body burdens. The blood serum PCB and DDE levels in a large cohort (538) of sport fish consumers for Lakes Michigan, Huron and Erie were significantly higher than in reference groups. Body burdens varied by exposure group, gender, and Great Lake. Years of consuming Great Lakes fish was the most important predictor of PCB levels, while age was the best predictor of DDE levels.

Falk *et al.,* (1999) examined fish consumption habits and demographics in relation to serum levels of dioxin, furan, and coplanar PCB congeners in one hundred subjects. Body burdens varied by gender and lake (Michigan, Huron, and Erie). Between-lake differences were consistent with fish monitoring data. Consumption of lake trout and salmon was a significant predictor of coplanar PCBs. Consumption of lake trout was also a significant predictor of total furan levels. Fish consumption was not significantly correlated with total dioxin levels.

***Health Effects***

Developmental, reproductive, neurobehavioral or neurodevelopmental, and immunologic effects of exposure to lipophilic pollutants (i.e. organochlorines) have been examined in studies conducted within the Great Lakes basin and outside the basin. The following are selected studies that have reported an association between exposure through sport fish consumption and these outcomes.

Developmental effects in the form of a decrease in gestational age and low birth weight have been observed in a Lake Michigan Maternal Infant Cohort exposed prenatally to PCBs (Fein *et al.,*, 1984). These findings have also been observed in offspring of women exposed to PCBs occupationally in the manufacture of capacitors in New York (Taylor *et al.,*, 1989).

Reproductive effects have also been reported. Courval and coworkers (1997 and 1999) examined couples and found a modest association in males between sport-caught fish consumption and the risk of conception failure after trying for at least 12 months. Studies of New York state anglers have not shown a risk of spontaneous fetal death due to consumption of fish contaminated with PCBs (Mendola *et al.,*, 1995), or an effect on time-to-pregnancy among women in this cohort (Buck *et al.,*, 1997).



Neurobehavioral or neurodevelopmental effects have been reported for exposure to PBT chemicals in newborns, infants, and children of mothers consuming Great Lakes fish. Early investigations of the Lake Michigan Maternal Infant Cohort revealed newborn infants of mothers consuming >6.5 kg/year of Lake Michigan fish had neurobehavioral deficits of depressed reflexes and responsiveness, when compared to non-exposed controls (Jacobson *et al.,*, 1984). The fish-eating mothers consumed an average of 6.7 kg of Lake Michigan contaminated fish per year equal to 0.6 kg or 2 to 3 salmon or lake trout meals/month. Prior to study admission, exposed mothers were required to have fish consumption that totaled more than 11.8 kg over a 6-year period. Subsequent studies of the Michigan Cohort have revealed neurodevelopmental deficits in short-term memory at 7 months (Jacobson *et al.,*, 1985) and at 4 years of age (Jacobson *et al.,*, 1990b), and also growth deficits at 4 years associated with prenatal exposure to PCBs (Jacobson *et al.,*, 1990a). A more recent investigation of Jacobson=s Michigan Cohort revealed that children most highly exposed prenatally to PCBs showed IQ deficits in later childhood (11 years of age) (Jacobson and Jacobson, 1996). Highly exposed children received prenatal PCB exposure equal to at least 1.25 ppm in maternal milk, 4.7 ppb in cord serum, or 9.7 ppb in maternal serum. The authors attributed these intellectual impairments to in utero exposure to PCBs.

The Oswego Newborn and Infant Development Project examined the behavioral effects in newborns of mothers who consumed Lake Ontario fish that were contaminated with a variety of PBT chemicals. These infants were examined shortly after birth (12-24 and 25-48 hours). Lonky *et al.,*, (1996) found that women who had consumed >40 PCB equivalent pounds of fish in their lifetime had infants who scored more poorly in a behavioral test (Neonatal Behavioral Assessment Scale) than those in the low-exposure (<40 PCB equivalent pounds of fish) or control group. In a follow-up study, Stewart *et al.,* (1999) concluded that the most heavily chlorinated and persistent PCB homologues were elevated in the umbilical cord blood of infants whose mothers ate Great Lakes' fish. The concentration was significantly dependent on how recently the fish were consumed relative to pregnancy. A further study attempting to relate the level of PCBs to scores in infants is underway.

Mergler and coworkers (1997) reported early nervous dysfunction in adults who consumed St. Lawrence River fish. However, in initial testing, neurotoxic effects were not observed by Schantz and coworkers (1999) in an elderly adult population (i.e. $50 years) of Lake Michigan fish-eaters with exposure to PCB and DDE. This study is ongoing. Immunologic effects have also been reported. Smith=s study (1984) demonstrated that maternal serum PCB levels during pregnancy were positively associated with the type of infectious diseases that infants developed during the four months after birth. In addition, incidence of infections has been shown to be associated with the highest fish consumption rate for mothers - i.e., at least three times per month for three years (Swain, 1991; Tryphonas, 1995).

Other health effects have been documented with PCB exposure. Elevated serum PCB levels were associated with self-reported diabetes and liver disease in cohorts of Red Cliff and Ojibwa Native Americans (Dellinger *et al.*,, 1997, Tarvis *et al.*,, 1997). Fischbein and coworkers (1979) found that workers exposed to a variety of PCB aroclors reported joint pain.

A summary of health effects studies inside and outside the Great Lakes basin can be found in the recent paper published by Johnson and coworkers (1998). Toxicological Profiles for hazardous substances, including PCBs and mercury, have been published by the U.S. Agency for Toxic Substances and Diseases Registry (ATSDR). The full reports can be obtained from ATSDR, and information is available on ATSDR=s website at http://www.atsdr.cdc.gov/toxpro2.html .

## 6.4 Human Health Indicators



Human health indicators have not yet been developed for the Lake Erie LaMP. However, a preliminary set of proposed human health indicators was forwarded as part of the LaMP's participation in the SOLEC'98 meeting focussed on *Indicators for the Great Lakes basin Ecosystem*. A preliminary suite of indicators is presented in Table 6.2.

Indicators are being developed as part of a number of initiatives, including SOLEC, LaMPs, the IJC Indicators Implementation Task Force, and the IJC Health Professionals Task Force. Health Canada has used existing data to develop a preliminary suite of health-related indicators as per the list above. They are published in the document *Health-Related Indicators for the Great Lakes Basin Population: Numbers 1-20* (Health Canada, 1998b). These indicators were presented at the State of the Lakes Ecosystem Conference (SOLEC) 1998. This is not meant to be a comprehensive list, but rather a springboard for discussion toward enhancing/revising these preliminary indicators and developing others.

### Table 6.2: Proposed Human Health Indicators for Lake Erie

| Human Health Indicator | Short Description |
|---|---|
| Environmental Health Indicators | Monitor for contaminants, including radionuclides, in various environmental media, including food originating in the Great Lakes basin (e.g. fish and wildlife), drinking water, recreational water, and air. Levels would be compared to current guidelines and standards. |
| Body Burden Indicator | Concentration of toxic contaminants in human tissue to serve as an indicator of exposure. |
| Health Effects Indicator | Traditional indicators such as cancer and birth defects. |
| Public Perception Indicator | Indicator to gauge if people are not using certain resources because of perceived health risks. |

## 6.5 Conclusion and Implementation Plan for Human Health

### Conclusions

For persistent bioaccumulative toxic chemicals, the current weight of evidence regarding human health effects is supportive of the need for continued reductions in the levels of PBT chemicals in the environment. While public health advisories and other guidelines can be followed to protect human health from current environmental exposures, continued reductions in the level of persistent pollutants in the environment, both globally and regionally, are ultimately the most effective long-term solution to minimizing the health risks to the Lake Erie basin population.

Although progress has been made in defining the health threat from Great Lakes pollutants (including Lake Erie pollutants), important issues remain requiring our diligent effort. To protect human health in the Lake Erie basin, actions must continue to be implemented on a number of levels. The Great Lakes Water Quality Agreement calls for ". . . develop[ing] approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health" (IJC 1987). For the public health arena, there are a number of issues that will help to identify these long-term, low-level health effects. Research in these areas will provide a more comprehensive view of the threat to human health from environmental contaminants, and enable public health agencies to utilize this knowledge to protect the public health more effectively. A shift in priorities is now needed to prevention, intervention, and collaborative activities, including the work of LaMPs. In particular, contaminant levels monitoring in environmental media and in human tissues is an activity in particular need of support, to better quantify the extent of exposure. Health risk communication is also a crucial component to protecting and promoting human health in the basin. The LaMP can play a key role in informing people about human health impacts of environmental contaminants and what they can do to minimize their health risks. This includes linking people to information that is packaged in a variety of ways and targeted to a range of audiences, to enable people to make informed choices about their health.

### Drinking Water

Over time, public water systems have been found to supply drinking water of good quality. Monitoring and corrective measures to reduce and eliminate levels of contaminants in treated water are essential components in continuing to assure the safety of drinking water supplies. As the population grows and more people rely on the drinking water supply from the lakes, these control measures must be adequate to reduce the risk from exposure to microbes in Great Lakes waters (Health Canada, 1997). Ultimately, however, source water protection (protection of the raw waters) is the key to maintaining the good quality of drinking water supplies. The Lake Erie LaMP has designated the drinking water use of Lake Erie as unimpaired (see Section 4).

### Recreational Use

Pollution controls and remediation, such as reducing combined sewer overflows, and improvements in sewage treatment, have continued to improve water quality in many areas of the Great Lakes basin in recent years. Long term planning for remediation of microbial contaminants in recreational water needs to include identification of sources of contamination, determination of which sources can be remediated and the costs involved, and timelines for implementation (Health Canada, 1998a; Lake Erie LaMP, 1999; U.S. EPA, 1998a). Although it may not be feasible to eliminate microbial level exceedances completely in recreational waters, it is expected that as sources continue to be remediated, exceedances will continue to decline. (Lake Erie LaMP, 1999; U.S. EPA, 1998a). The Lake Erie LaMP has designated recreational use as impaired (see Section 4).

### Fish Consumption

Diet contributes over 95% of the PBT chemical intake for the general population, with drinking water, recreational water, and air constituting very minor exposure routes. Consequently, the approach by various public health agencies has been to focus on groups at higher risk of exposure to PBT chemicals from Great Lakes sources, such as high consumers of sport fish. Due to the presence of PCBs, organochlorine insecticides, mercury, and other chemicals in fish from the Lake Erie basin, fish advisories are issued which recommend restrictions on fish consumption. Tighter restrictions are recommended for pregnant women, women of childbearing age and children, in some cases to the point of completely eliminating fish from the diet. When communicating health risk information to fish consumers, it is important to remember that fish are also a good source of low-fat protein, and that the activity of sport fishing has social and cultural benefits.



### Additional Exposure and Health Effects Research for PBT Chemicals

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin, leading to declines in levels in the environment, and in animal and human tissues. Within the ecosystem, there are encouraging signs and successes. For example, contaminant declines have been observed at most Great Lakes sites sampled for contaminants in the eggs of herring gulls (Environment Canada and U.S. EPA, 1999).

Reductions of PBT chemicals in human tissues include lead in blood and organochlorine contaminants in breast milk. This translates into a reduced risk to health for these contaminants. However, PBT chemicals, because of their ability to bioaccumulate and persist in the environment, continue to be a significant concern in the Lake Erie basin. Human health research has identified fish consumption as the major pathway of exposure to contaminants from Lake Erie and other Great Lakes. Body burdens from consumption of contaminated fish have been noted in highly exposed populations and human health effects have subsequently been reported. Despite these findings, issues related to environmental exposures and human health still remain. This supports the need for continued reductions of PBT chemicals in the Lake Erie basin. Health research needs to continue, but a shift in priorities is now needed to prevention and intervention strategies. Efforts on public health advisories to protect health from current environmental exposures, and public outreach related to risks and benefits of fish consumption, need to continue where appropriate.

Additional research is needed in the following areas:

1. Continue to assess the role of PBT chemicals on neurobehavioural and neurodevelopmental effects.
2. Improve the assessments of chemical mixtures.
3. Assess the role that endocrine disruption may play in human health effects, such as reproductive health.
4. Research on PCB congeners.
5. Research on biologic markers.

Recommendations for public health interventions and research have been identified throughout the paper. Proposed and ongoing actions to further public health intervention and research are presented in Table 6.3.

## Table 6.3 Human Health Action/Implementation Plan Matrix

| Description | Project Lead | Funding Status |
|---|---|---|
| **Drinking Water** | | |
| Assess sources of drinking water.<br>• For the U.S., U.S. EPA and all the Lake Erie states, tribes and local water utilities have adopted a Source Water Protection Protocol for use in source water assessments to be conducted by 2003. The standardized protocol for conducting assessments of public drinking water supplies will delineate source areas and assess significant potential sources of contamination in order to protect water supplies and inform beach managers.<br>• In Canada (Ontario), assessment of drinking water supply sources is done by the Ontario Drinking Water Surveillance Program and reported to the public. | U.S. states working with U.S. EPA and local communities<br><br>Ontario Drinking Water Surveillance Program | A<br><br>A |
| Protect drinking water sources. This would include specific actions such as: wellhead protection plans and protection plans for water supply intakes on Lake Erie | U.S. states working with U.S. EPA and local communities; Health Canada/Ontario/local communities | A |
| Raise awareness and publicize the availability of drinking water monitoring information to the general population B Confidence Reports, U.S., Drinking Water Surveillance Program, Ontario. | U.S. and Canadian Water Systems; state/provincial and federal health and environmental agencies; local governmental agencies | A & B |
| Promote epidemiological research (exposure and health effects) on drinking water borne diseases in the Great Lakes and for the Lake Erie basin in particular. This should include an evaluation on public vs. private sources. | Funded research from NIEHS, U.S. EPA, Health Canada and academic researchers | A & B (funding needs to be targeted towards the Great Lakes) |
| Continue to research the implications of aluminum and chlorination disinfection by-products on human health and promote the development of guidelines for water treatment to minimize any risk to health that may exist. | U.S. EPA, Health Canada/ Ontario | A |
| Improve the identification/diagnosis and promote the reporting of water borne disease incidences to help in response to disease outbreaks, improving information for epidemiological studies and for tracking trends over time (indicator). | U.S. CDC, state and local health departments; Province of Ontario and local Health Units | C |
| Research and development of technologies and methods for the detection and treatment of Giardia, Cryptosporidium and other parasites in drinking water to protect human health. | U.S. federal and state health agencies, U.S. EPA; Health Canada | A & B |
| Promote ambient monitoring of Lake Erie drinking water intakes, and tributaries that can potentially degrade water quality at these intakes, and storage of data in electronic databases. Microbiological and turbidity monitoring should be included in the monitoring program. | IJC Indicator Implementation Task Force; U.S. EPA OGWDW; EPA GLNPO; Great Lakes Commission | A & B (In Canada this is done and reported. U.S. may be done but not required to be reported.) |

| Description | Project Lead | Funding Status |
|---|---|---|
| **Recreational Water** | | |
| Continue to promote and expand the U.S. BEACHs surveillance program and corollary programs for the Canadian shoreline. This would include outreach to local governments along the Lake Erie shoreline for their involvement. In parallel a Lake Erie indicator of recreational water quality that includes microbial data supplemented by beach postings should continue to be developed. | U.S. EPA; Health Canada; state/provincial and local governments. | A |
| Continue the development of rapid sampling technologies and techniques for microbial and viral contamination and promote the dissemination and use of the instrument and sampling methods to local governments along the Lake Erie shoreline. | U.S. EPA BEACHs program; Health Canada; Ontario, state and local governments | A & B |
| Promote epidemiological research on recreational water borne diseases in the Great Lakes and for the Lake Erie basin in particular. This should also include research on the health implications of interstitial bathing waters, CSO/SSO discharges and inhalation of water spray. | Funded research from NIEHS, U.S. EPA, Health Canada and academic researchers | A & B |
| **Fish Consumption** | | |
| Research the health benefits of fish consumption to better quantify those benefits for use in risk assessment for developing fish consumption advice. | U.S. EPA/OST | B & C |
| Develop a meaningful Lake Erie indicator for fish consumption. Promote the reporting of contaminant levels in edible portions of fish collected by state agencies responsible for fish consumption advisories. Indicator would track these levels over time. | Lake Erie LaMP partners, SOLEC | A & B |
| Increase awareness, use and effectiveness of fish advisories in the Lake Erie populations targeting sensitive populations (minorities, women of childbearing age, immigrants, the elderly, etc.) | State and Province Government Agencies, U.S. EPA, Health Canada, local governments | A & B |
| • U.S. EPA grant to Delta Institute for Outreach of Fish Consumption Advisories to Minority and At Risk Populations This is a pilot grant to develop and promote the outreach of fish consumption advice to minority and at risk populations in the Lake Erie Basin. The grant emphasizes the development and promotion of culturally sensitive and effective outreach materials. | U.S. EPA | A |
| • ATSDR grant to Consortium for the Health Assessment of Great Lakes Fish Consumption<br>This is an ongoing project to conduct a Great Lakes basin wide outreach program to distribute sport-fish advisory materials to women of childbearing age and to host a conference to establish a forum for exchange of information on successful distribution of the sport fishing advisory to women of childbearing age and other high risk populations. The Consortium of Great Lakes states developed outreach materials for women of childbearing age and minority groups which are being utilized by seven of the eight Great Lakes states (Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin). These outreach materials such as posters and recipe cards are being adapted by each of the states for their specific needs, and are being distributed at women and children's clinics, health fairs, state fairs, and fishing shows to increase health advisory awareness. | ATSDR/State of Wisconsin | A |

| Description | Project Lead | Funding Status |
|---|---|---|
| **Exposure and Health Effects Research** | | |
| Promote exposure, outcome and epidemiological research for PBT chemicals in the Great Lakes and specifically within the Lake Erie basin. This research should include the five needs for the future listed in Section 6.5. | ATSDR; NIEHS; U.S. EPA; Health Canada; Environment Canada; state, provincial and local health departments | A & B |
| • Shoreline Survey - In a recent Health Canada study carried out in five Areas of Concern in the lower Canadian Great Lakes (Dawson, 2000), 4,637 shoreline fishers were interviewed. The demographic data show that there is no such thing as a Atypical@ fisher. People who like to fish come from different cultural backgrounds, are different ages and have different occupations. A report of the results is expected to be available by mid-year 2000. | Health Canada | A |
| • Great Lakes Fish Eater Study - A concurrent project, the Great Lakes Fish Eaters Study (not yet released) has taken a more in-depth look at exposure to environmental contaminants in people eating large amounts of Great Lakes fish. Environmental contaminant levels were measured in blood samples collected from the study participants. As well, nutritional and social benefits associated with consumption of Great Lakes fish were examined. | Health Canada | A |
| **Other** | | |
| Development of a Human Health Resource Home Page for the Great Lakes with pages specifically oriented towards human health issues in the Lake Erie basin | LaMP HH Subcommittee; U.S. EPA; Health Canada; ATSDR; States and Provinces working with the Great Lakes Commission and other LaMP partners | B |
| Assessment of social dimensions of health in the Lake Erie basin. Identify references available, and the need to address the social dimensions of health, further to the WHO definition of health. | LaMP HH Sub-committee and Public Forum HH Task Group, working with LaMP partners; Health Canada; U.S. EPA | B |
| Literature review of wildlife consumption issues. | | B |

***Funding Status Codes:**

A. Funded actions

B. Unfunded actions (or uncommitted — those actions which are high priority for the committee or a state/tribe but no funding presently exists)

C. Future Actions (those actions that are on your wish list but are “not ready for prime time”)

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