Chapter 5

Human Health

Fishing along Lake Superior
Photograph by: Lake County Forest Preserve District

Lake Superior Lakewide Management Plan
2000

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EXECUTIVE SUMMARY

Purpose

The 1987 Protocol to the Great Lakes Water Quality Agreement (GLWQA) states that Lakewide Management Plans for open lake waters shall include "A definition of the threat to human health or aquatic life posed by Critical Pollutants." The goal of the human health chapter of the Lake Superior LaMP 2000 is to fulfill the human health requirements of the GLWQA, including describing the potential adverse human health effects arising from exposure to persistent, bioaccumulative, toxic chemicals (PBT chemicals) as well as other contaminants of health concern (including microbial contaminants) in the Lake Superior basin.

What's Included

The human health chapter for the Lake Superior LaMP has:
- identified potential human health implications from contaminants in the Lake Superior environment;
- discussed current programs and strategies designed to protect human health;
- developed an action plan to continue to protect human health; and
- proposes a suite of human health related indicators.

Background

Exposure to environmental contaminants through recreational water use, air, soil, and food consumption are discussed in detail, with particular emphasis on the existing evidence for human health effects from exposure to PBT chemicals through food, especially consumption of Great Lakes fish.

Microbial contamination of drinking water can pose a potential public health risk in terms of acute outbreaks of disease. Gastro-intestinal disorders and minor skin, eye, ear, nose and throat infections have been associated with microbial contamination of recreational waters.

Demonstrating health effects in humans from chronic, low-level exposure to PBT chemicals typically encountered in the Great Lakes region poses a challenge for researchers. For example, human epidemiological studies are limited in their ability to separate health effects attributable to contaminant exposures from those related to other known health factors like smoking, alcohol intake and general health status. Despite these limits, neurodevelopmental and reproductive effects have been reported in some studies of human populations in the Great Lakes basin. In addition, developmental effects have been observed in wildlife and laboratory studies of PBT chemicals. Therefore, in defining the threat to human health from exposure to contaminants in the Lake Superior basin, a weight of evidence approach is often used, where the overall evidence from wildlife studies, experimental animal studies, and human studies is considered. These human and wildlife studies are sufficient to suggest that human health is at risk from exposure to PBT chemicals, and may have profound implications for the population.

Conclusions

Progress continues to be made to reduce the risk to health from exposure to environmental contaminants in the Great Lakes basin. Since the 1970's, there have been steady declines in many PBT chemicals in the Great Lakes basin, leading to declines in levels in human tissues, for example, lead in blood, and organochlorine contaminants in breast milk. This translates into a reduced risk to health for these contaminants.

The following are the specific conclusions from the paper:

- Drinking water is generally of good quality but continued efforts towards the detection and treatment of microbial contaminants is important to reduce risk of acute water borne disease.
- Although it not possible to document the risk to health from contaminants in recreational water quality, exposure levels of health concern have been documented in the Lake Superior basin.
- While the average person within the Lake Superior basin does not eat enough fish and wildlife to pose a risk to their health, there are some people who do. People who eat a lot of fish, regularly eat large predator fish, eat fish from highly contaminated waters, or eat a lot of fish over a short period of time are at increased risk of exposure and health effects. In addition the developing fetus and young children are at greater risk than adults. Although fish consumption programs are well established in the basin, studies show that only half of the population are aware of these advisories.
- For the Lake Superior basin the current weight of evidence regarding human health effects is sufficient to support the continued reductions in the levels of PBT chemicals in the environment.

Actions

To protect human health, actions must continue to be implemented on a number of levels. Reductions and monitoring of contaminant levels in environmental media and in human tissues is an activity in particular need of support. Health risk communication is also a crucial component to protecting and promoting human health in the Lake Superior 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.

The four priority areas of activity for human health, further elaborated on in the Implementation Plan/Action Matrix presented in Section 5.5 of the chapter, are:

- continued reduction of contaminants to the Lake Superior ecosystem (virtual elimination, beginning with the zero discharge demonstration program)
- monitoring contaminant levels in the environment and in human tissue to help determine extent of exposure;
- support the continued research into the linkages between environmental contaminants and human health outcomes; and
- communicating health risks and how to minimize them.

After the release of the LaMP 2000 document in April, several actions will be taken to continue progress toward reducing the risk to human health from exposure to environmental contaminants. Figure 5-1 is a summary of human health actions, the lead agency for implementation, and the funding status.

Figure 5-1. Action Summary

Project	Lead Agency/ Funding Source	Funded	Needs Funding
Improve Effectiveness of Fish Consumption Advisories for Mercury Contaminated Sport Fish Project	WI and ME - U.S. EPA funded	X	
Increase Awareness of Great Lakes Fish Consumption Advisories among Women of Childbearing Age	Great Lakes States - ATSDR funded	X	
Fish Consumption Study	GLIFWC	X	
Qualitative Risk/Benefit Analysis of Fish Consumption	U.S. EPA OST	X	
Preparation and Implementation of Protection Plans for Water Supply Intakes on Lake Superior	Great Lakes States and U.S. EPA	X	
Analysis of mercury in hair from MN Lake Superior basin residents			X
Screen fish from U.S. Lake Superior Basin for suite of OCCs - as PCBs decline other OCCs will become an issue			X
Literature review of wildlife consumption issues			X
Quantitative Risk/Benefit analysis of fish consumption			X
Need a better understanding of the chemical reactions and interactions in the transition zone between groundwater and surface water, to facilitate quantitative risk assessment of the potential effects of PBT contaminated sediments.			X
Promote the use of E. Coli testing and methods over fecal coliform (training video distribution).	U.S. EPA	X	
Promote beach monitoring programs in areas where they do not exist.			X
Promote reporting of results to the U.S. EPA BEACHs Program.			X
Promote the communication of risks (advisories and closures) to the public.			X
Water Quality Indicators Research: Cost effective real time monitoring/assessment methods need to be developed.			X
Development of effective modeling/monitoring to better estimate/predict beach/water exceedences.	U.S. EPA, Health Canada	X	
Exposure and health effects research: epidemiological research into the relationships between beach/water indicators and health outcomes. Research on the interstitial zone.	U.S. EPA, USGS, Health Canada	X	

Figure 5-1. Action Summary

Project	Lead Agency/ Funding Source	Funded	Needs Funding
EPA will be developing policies to ensure that states and tribes adopt the currently recommended *Ambient Water Quality Criteria for Bacteria - 1986* and make the transition to monitoring for E. coli and enterococci indicators rather than total coliforms or fecal coliforms.	U.S. EPA	X	
EPA will also develop a national inventory of digitized beach maps which will be linked with locations of pollution sources through a Geographic Information System.	U.S. EPA	X	
EPA is proposed to conduct research to determine pathogen occurrence and indicator relationships associated with wet weather flows.	U.S. EPA	X	
U.S. EPA is developing and supporting efforts related to the protection of recreational waters, which may include training in new methods, other technology transfer opportunities, and guidance implementation. The EPA is currently in the process of developing National Guidance for Recreational Beach Managers, which will be used as a guidance tool for public health officials and other recreational water quality monitoring officials to reduce the risk of disease to users of recreational waters through improvements in water monitoring and public notification programs. A training video for Recreational Beach Managers is expected to be completed and distributed by mid-year, 2000.	U.S. EPA	X	

5.0 ABOUT THIS CHAPTER

There is concern about the effects that Great Lakes contaminants, and in particular persistent, bioaccumulative toxic chemicals (PBT chemicals), have on human health. The Revised Great Lakes Water Quality Agreement of 1978 (GLWQA), as amended by Protocol signed November 18, 1987, states that Lakewide Management Plans (LaMPs) for open waters shall include "A definition of the threat to human health or aquatic life posed by Critical Pollutants". The goal of the Lake Superior LaMP Human Health chapter 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 Superior basin;
- to address current and emerging human health issues of relevance to 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.

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 ..." (World Health Organization 1984). Therefore, when considering 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 are one among many factors that contribute to the state of our health (Health Canada 1997). It is important to consider the complete range of factors that influence health, and the complex interactions between these factors, when investigating the role of environmental contaminants as a causal factor in health outcomes .

Consideration of human health in the Lake Superior basin must also take into account the diversity of the Lake Superior basin population, which includes a range of cultural groups including aboriginal peoples. Certain subpopulations, such as high fish consumers, may have higher exposures to persistent toxic chemicals than the general population, and therefore may be at increased risk of suffering adverse health effects. In addition, some exposed subpopulations, such as the elderly, women and men of child-bearing age, the fetus, nursing infants, children, and the immunologically compromised, may be more susceptible to the effects of PBT chemicals (Johnson and others 1998, Health Canada 1998d). Therefore, the discussion of health issues in this chapter looks at the health of the general population as well as subpopulations at increased risk of exposure and health effects.

The Native American/aboriginal populations in the Great Lakes basin represents an important population at increased risk of exposure to environmental contaminants, and therefore may be at increased risk of suffering adverse effects. Higher exposures in these populations are the result of the strong cultural relationship between those populations and their environment. Spiritual, medicinal, hunting, gathering and fishing traditions increase the number of exposure routes for this population. For example, Native Americans in the Great Lakes have much higher fish consumption rates than those accounted for by current methods used to devise water quality criteria. Also, Native Americans in the region harvest other natural resources that are potential sources of exposure, including the consumption of deer livers and wild rice. Both of these represent additional routes of exposure to trace heavy metals (such as cadmium) that are known to accumulate in wild rice and livers of deer.

Of the several hundred environmental contaminants found in the Great Lakes basin, the International Joint Commission (IJC) has identified eleven chemicals (designated as “Critical Pollutants”) to be of greatest concern because they are persistent in the environment and bioaccumulate in the food chain. Food, in particular the consumption of Great Lakes fish, is the primary route of human exposure to these PBT chemicals. The nine chemicals designated for zero discharge demonstration for Lake Superior (see Chapter 4 for list) are a subset of the eleven Great Lakes Critical Pollutants identified by the IJC. These chemicals have caused developmental defects, cancer, and other chronic diseases in laboratory animals, fish, and wildlife (Health Canada 1998d). This has raised concern about their effects on human health, and research is focused on quantifying human exposure and determining health effects, particularly in sub-populations such as high fish consumers.

Demonstrating health effects in humans from chronic, low-level exposure to PBT chemicals typically encountered in the Great Lakes region poses a challenge for researchers. For example, human epidemiological studies are limited in their ability to separate health effects attributable to contaminant exposures from those related to other known health factors like smoking, alcohol intake and general health status. Despite these limits, neurodevelopmental and reproductive effects have been reported in some studies of human populations in the Great Lakes basin. In addition, developmental effects have been observed in wildlife and laboratory studies of PBT chemicals. Therefore, in defining the threat to human health from exposure to contaminants in the Lake Superior basin, a weight of evidence approach is often used, where the overall evidence from wildlife studies, experimental animal studies, and human studies is considered. These human and wildlife studies are sufficient to suggest that human health is at risk from exposure to PBT chemicals, and may have profound implications for the population.

Descriptions of the nine zero discharge chemicals can be found at http://www.cciw.ca/glimr/lamps/lake-superior/ . In addition, detailed toxicological profiles describing the health effects of these chemicals have been published by the U.S. Agency for Toxic Substances and Diseases Registry (ATSDR; see list of titles under Section 5.7 of this Chapter - "Internet Information Resources and Further Reading Lake Superior Human Health Issues").

Since the 1970s, there have been steady declines in many PBT chemicals in the Great Lakes basin, leading to declines in levels in human tissues -- lead in blood, and organochlorine contaminants in breast milk. For example, composite levels of seven persistent organochlorine pesticides (including DDT and its metabolites, dieldrin, oxychlordane [a metabolite of chlordane] and HCB) in human breast milk in Canada have declined 80 percent since 1975 (Craan and Haines 1998). 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 Superior basin. Therefore, remediation and pollution prevention measures to continue to reduce contaminant levels in the Lake Superior basin should be continued, while at the same time public health advisories and other guidelines should be followed to protect human health from current environmental exposures.

Section 5.1 of this chapter describes the pathways of exposure relevant to human health and also provides information on the status for Lake Superior, public health protections in place and needs for the future for drinking water, recreational water, air pollution, soils/sediments and fish/food consumption; Section 5.2 explains and applies a weight of evidence approach to looking at potential health effects from PBT chemicals and identifies futures research needs; Section 5.3 describes proposed indicators of human health; Section 5.4 provides an overall conclusion and recommended actions to be taken to protect human health; Section 5.5 is a glossary of terms for this Chapter; Section 5.6 lists Lake Superior relevant human health Internet resources; and Section 5.7 contains the references for this Chapter.

5.1 EXPOSURE PATHWAYS AND RELEVANT HUMAN HEALTH ISSUES

The three major routes that chemical and microbial pollutants enter the human body are by ingestion (water, food, and also soil - particularly in the case of children), inhalation (airborne), and dermal contact (skin exposure). In addition, the long-range transport of PBT chemicals is a major source of deposition to the Lake Superior basin. Although it is not a pathway of direct human exposure to persistent contaminants, long-range transport represents an indirect exposure because it provides a significant source for contaminants that accumulate and magnify in the Lake Superior basin food chain.

The Critical Pollutants and Prevention Pollutants for Lake Superior include organochlorines such as PCBs and toxaphene, and metals such as lead and mercury (for a complete pollutants list for the Lake Superior basin see Lake Superior LaMP Stage 2: Load Reduction Targets for Critical Pollutants 1998). These chemicals do not break down easily, tend to persist in the environment, and bioaccumulate in biota and animal and human tissues -- thus they are called Persistent Bioaccumulative Toxic chemicals (PBT chemicals). Organochlorines tend to accumulate in fat (such as adipose tissue and breast milk), and metals tend to accumulate in organs and flesh. The major route of exposure for these PBT chemicals is through food, including fish consumption (Health Canada 1998e, Johnson and others 1998). Sources from air, soil/dust, and water, including the lakes themselves, constitute a minor route of exposure (Health Canada 1998e). Most of the health effects studies for Great Lakes PBT chemicals have focused on fish consumption. These studies are discussed in Section 5.2 of this Chapter.

The human health ecosystem objectives developed for the Lake Superior LaMP are related to the exposure pathways identified above, and are outlined in Table 5-1.

Table 5-1 Health Related Ecosystem Objectives for Lake Superior LaMP and Pathways of Exposure

Ecosystem Objective	Pathway of Exposure	Contaminant of Primary concern
Overall Human Health Objective: The health of humans in the Lake Superior ecosystem should not be at risk from contaminants of human origin.		
Fish and wildlife in Lake Superior ecosystem should be safe to eat; consumption should not be limited by contaminants of human origin.	Food/fish consumption	PBT chemicals i.e. organochlorines, methylmercury
Water quality in Lake Superior should be protected where it is currently high, and improved where it is degraded. Surface waters and groundwater should be safe to drink after treatment to remove natural impurities and micro-organisms.	Drinking water (includes water used for cooking, and used in preparation of beverages)	microbial contaminants (primary health concern); chemicals such as aluminum, nitrates
The waters of Lake Superior should be safe for total body contact activities, even adjacent to urban and industrial areas.	Recreational water use that involves total body contact with water (incidental ingestion, dermal contact, inhalation)	microbial (primary health concern); chemicals such as PAHs.
Air quality in the Lake Superior ecosystem should be protected where it is currently high, and improved where it is degraded. Communities, industries and regulators outside the Lake Superior ecosystem should be informed of the consequences of long-range atmospheric transport of contaminants into the Lake Superior basin.	Direct inhalation, and also atmospheric deposition and subsequent bioaccumulation of PBT chemicals through the food chain	Inhalation: Chemicals such as ozone, sulphates, acidic air pollutants, particles; Atmospheric deposition: PBT chemicals
Soils in the Lake Superior ecosystem should not present a hazard to human health through direct contact, dust inhalation or ingestion, groundwater contamination, or crop contamination	Ingestion of soils; Sediments - indirect exposure through food chain	PBT chemicals i.e. organochlorines, methyl mercury

Exposure to compounds in different types of environmental media (e.g. air, soil, groundwater...) may be expected to have different effects or to affect humans with different levels of severity. For example, chromium IV (chromium with a charge of +6) is a potent carcinogen when inhaled from air and yet it has been shown to change chemically when ingested, in the gastro-intestinal (GI) tract, to relatively non-toxic chromium III (chromium with a charge of +3). Furthermore, the likelihood of exposure may be different for chemicals in different media. Lead in grass covered soil is unlikely to be ingested by anyone except a pica (soil eating) child, yet lead in dust or unvegetated soil may stick to skin, be inhaled, or be ingested with food. Many compounds when found in surface waters may compromise the health of aquatic organisms, but are not expected to impact humans. Depending on the chemical contaminant or ambient concentration in the water, this may be because aquatic organisms live enveloped in surface waters, or because people do not typically drink untreated surface waters. While exposure to some compounds in turbid or agitated water, like PAHs, can cause irritation of the skin or, potentially, other adverse human health effects, these levels of contamination will typically kill or severely restrict populations of aquatic organisms, especially benthic organisms.

5.1.1 Environmental Contaminants in Lake Superior Basin Drinking Water

Access to clean drinking water is essential to good health. The waters of Lake Superior and surrounding areas are a primary source of drinking water for the people who live in the Lake Superior basin. The Great Lakes Water Quality Agreement designates "restrictions on drinking water consumption, or taste and odour problems" as an impaired beneficial use -- note that "taste and odor" is an aesthetic impairment as opposed to a health-related impairment (IJC, Annex 2.1.c. 1987).

While there has been an overall reduction of contaminants in the Great Lakes basin since the 1970s, contamination of the lakes through human activity continues to be of public and scientific concern. Since the most common way for people to be exposed to contaminants in water in the Great Lakes basin is through the drinking water supply, the potential health effects are of particular importance (Health Canada 1995a).

The province of Ontario, and three U.S. states, Michigan, Minnesota and Wisconsin, border Lake Superior, and although many of the communities within the basin are sparsely populated, approximately 650,000 residents on the U.S. side and upwards of 200,000 residents (including 130,000 on communal water) on the Canadian side of the Lake Superior basin use basin water for drinking, cooking, bathing, and other household uses. This water is obtained from a variety of suppliers, both public and private. Public suppliers provide water which is drawn from either surface water sources (including Lake Superior and/or surrounding waters), groundwater sources, or from a combination of these sources. For private suppliers, a large portion of permanent and seasonal residents use private water supply systems, water is drawn from wells or surface water sources (Health Canada 1998b).

In Minnesota and Wisconsin, the communities that draw their drinking water directly from Lake Superior are Grand Portage, Grand Marais, Silver Bay, Beaver Bay, Two Harbors, Duluth, (Cloquet uses Lake Superior as a backup water supply), Ashland and Superior. Michigan communities which use Lake Superior as a drinking water source are Marquette, Baraga, L'Anse and Sault Ste. Marie. In Ontario, communities that draw their drinking water directly from Lake Superior include Rossport, Terrace Bay, and Thunder Bay. (Thunder Bay has two treatment facilities, one drawing its water from Lake Superior [Bare Point Water Treatment Plant], and the other drawing its water from Loch Lomond, an inland lake). The remaining communities within the Lake Superior basin use inland lakes or rivers (surface water) and/or groundwater to supply drinking water. At present none of the eight Areas of Concern (AOC) in the Lake Superior basin list restrictions on drinking water as a use impairment in their Remedial Action Plans (for more information on Lake Superior AOCs go to: http://www.cciw.ca/glimr/raps/intro.html)

A variety of contaminants can adversely impact drinking water, including micro-organisms (e.g. bacteria, viruses, and protozoa such as Cryptosporidium), chemical contaminants (including naturally occurring chemicals and anthropogenic [synthetic] chemicals), and radiological contaminants -- including naturally-occurring inorganic and radioactive materials (IJC 1996, Health Canada 1997, Lake Erie LaMP 1999, OME 1999). Some contaminants of raw water supplies, such as aluminum, arsenic, copper, and lead, can be both naturally occurring and/or result from human activities. Other contaminants, such as household chemicals, industrial products, urban storm water runoff, fertilizers, human and animal waste, nitrate (from fertilizers and sewage), and pesticides may also end up in raw water supplies (U.S. EPA 1999f, Health Canada 1998b).

Some individuals or groups, particularly children and the elderly, may be more sensitive to contaminants in drinking water than the average person (Health Canada 1993). Although drinking water quality guidelines are for the general population, they are based on health effects observed in the most sensitive subgroup of the population (e.g. lead and children).

5.1.1.1 Microbial Contaminants

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 of a gastro-intestinal nature, although some pathogens are capable of causing severe and life-threatening illness (Health Canada 1995a). In most communities, drinking water is treated to remove contaminants before being piped to consumers, and microbial 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, we have virtually eliminated diseases such as typhoid and cholera. Although other disinfectants are available, chlorine still tends to be the treatment of choice. When used with multiple barrier systems (i.e. coagulation, flocculation, sedimentation, filtration), chlorine is effective against virtually all infective agents. (U.S. EPA/Government of Canada 1995; Health Canada 1993, 1997, and 1998).

In Canada and the U.S., community water suppliers deliver high quality drinking water to millions of people every day, and a network of government agencies are in place to ensure the safety of public drinking water supplies (OGWDW 1999a) But although our drinking water is safer today than ever, problems can, and do, occur, although they are relatively rare. Localized outbreaks of water-borne disease have been linked to contamination by bacteria or viruses, probably from human or animal waste (U.S. EPA 1999f).

Recently, there has been increasing concern over the presence in drinking water of parasites such as Giardia and Cryptosporidium (the most common source of which is animal feces), which are resistant to common disinfection practices, and may pass through water treatment filtration and disinfection processes in sufficient numbers to cause health problems (Health Canada 1998a). For example, in 1993, Milwaukee, Wisconsin experienced a widespread outbreak of cryptosporidiosis that affected over 400,000 residents, causing severe diarrhea, nausea, stomach cramps, and other symptoms. While most people recovered without treatment, the outbreak contributed to the deaths of at least 100 people already ill with AIDS-related illnesses, cancer or other maladies. The outbreak was caused by Cryptosporidium oocysts that passed through the filtration system of one of the city's two water-treatment plants (WI DNR 1994, WI DNR 1998, Health Canada 1997).

Thunder Bay Drinking Water Case Study

In October 1997, the Medical Officer of Health for the Thunder Bay District Health Unit issued a Boil Water Advisory to the residents of the south side of the city of Thunder Bay following the receipt of a laboratory report confirming the presence of Giardia in the water distribution system. The cyst was found on routine testing in the post-treated water supply in the south section of the city. In consultation with the Ministry of Health, Ministry of Environment, and city officials it was agreed that due to lack of a barrier filtration system, the advisory was made to inform the public who were supplied by the compromised system to a potential threat of water-borne disease.

During the 13 months of the Boil Water Advisory, the city undertook the installation of a temporary filtration plant to ensure that water from its Loch Lomond site was safe for its consumers. Once completed, and having met the minimum requirements of the Ministry of the Environment, the Boil Water Advisory was lifted on November 8, 1998. Plans by the city are underway to expand its water treatment facilities in the north end of the city to provide filtered treated water to the entire city from one source.

Boiling water is the best method for killing Cryptosporidium and bacteria in emergency situations (Health Canada 1997) and boil water orders are generally the standard public health protection method when drinking water is found to be contaminated. Since the Milwaukee outbreak, U.S. EPA has strengthened treatment requirements and standards for public water supplies using surface water. Health Canada, in collaboration with the provinces, is currently developing a drinking water guideline for Giardia and Cryptosporidium, is reviewing its turbidity guideline, and recently published a document titled "Guidance for Issuing and Rescinding Boil Water Advisories" (November 1998, revised March 1999), as a tool for health and environment authorities who must make the decisions concerning boil water advisories. These guideline documents can be found at Health Canada's web site at: http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/dwgsup_doc.htm

5.1.1.2 Chemical Contaminants

Certain chemical contaminants are of concern in drinking water because of possible health concerns associated with exposure to these substances. These contaminants may be in the raw (untreated) water as a result of industrial and agricultural activities, or treated wastewater discharges (MPCA 1997). Some may also be present in the treated water as a result of chemicals used in the drinking water treatment process (Health Canada 1998b). A snapshot of some chemical contaminants of concern (including aluminum, chlorination disinfection by-products, and contaminants in groundwater) is presented below.

Food, including fish consumption, is the primary route of exposure to PBT chemicals, including the nine chemicals designated as zero discharge contaminants for Lake Superior. Previous assessments for the Canadian Great Lakes basin (Health Canada 1998b) show the intake of PBT chemicals via drinking water is negligible (less than 1 percent of total intake from all sources). They are well below the Maximum Acceptable Concentration (MAC) listed in the Ontario Drinking Water Objectives (OME 1994) and the Guidelines for Canadian Drinking Water Quality (sixth edition, Health Canada 1996). For the U.S. Great Lakes basin including Lake Superior, measured levels of these persistent toxic chemicals in drinking water are below the Maximum Contaminant Levels (MCLs) in Lake Superior, and therefore they are not considered to be a human health concern for drinking water. (Personal communication Doug Mandy, Minnesota Department of Health, 2000).

Public water systems use various processes in order to treat raw water. One process involves the addition of alum, an aluminum compound that is used for the coagulation of suspended solids. Subsequently, the use of alum in the treatment process can raise the levels of aluminum in drinking water if the process is not optimized. If the quality of the raw water is poor, it may affect the amount of aluminum that needs to be added. There is much debate as to the role aluminum may play in the development of Alzheimer's Disease and other dementias (Health Canada 1997, Health Canada 1998b).

Currently, the U.S. EPA does not regulate aluminum under its drinking water program but has a secondary, non enforceable standard of 50-200 µg/l (this number is based on organoleptic properties). The U.S. EPA is working to determine if aluminum is of health concern and has placed aluminum on its Contaminated Candidates List (CCL). This list is the source of priority contaminants for the Agency's drinking water program. Priorities for drinking water research, occurrence monitoring, guidance development, including the development of health advisories will be drawn from the CCL. The CCL also serves as the list of contaminants from which the Agency will decide whether of not to regulate specific contaminants.

Other processes commonly used by water treatment plants include the addition of disinfectants such as chlorine to inactivate or kill micro-organisms in the distribution system. However, chlorine and other disinfectants can combine with naturally occurring organic matter in the raw water to produce disinfection byproducts. Of the chlorination disinfection byproducts, trihalomethanes (THMs) are present in the highest quantities. Evidence from toxicologic and epidemiologic studies suggests a possible link between byproducts of the chlorination process and increased risk of some cancers (e.g., bladder and colon) and adverse pregnancy outcomes (e.g., miscarriage, birth defects and low birth weight). The amount of chlorination required and resulting levels of chlorination disinfection byproducts are dependent upon the quality of the raw water, including microbiological quality and organic content (Health Canada 1995a, 1997). Zebra mussel control at drinking water intakes can also result in increased levels of disinfectants and disinfection byproducts in finished drinking water. Nutrient enrichment in source waters can cause algal blooms which contribute to total organic carbon levels. In the U.S., EPA is developing standards to address the issue of disinfectants and disinfection-by-products. In Canada, Health Canada re-opened the THMs guideline in April 1998 and established a multi-stakeholder Task Group to oversee a comprehensive update of health risk information on THMs and to develop recommendations for controlling the risks.

Some materials in soils are naturally-present (example arsenic, mercury) and can become dissolved or suspended in groundwater. Groundwater can also pick up materials of human origin that have been spilled or buried in dumps and landfill sites, or that have resulted from agricultural activities (example nitrates, atrazine). Contamination can therefore occur both in urban/industrial areas, and in rural/agricultural areas (U.S. EPA 1995, Health Canada 1998b).

5.1.1.3 Protecting Public Health - Regulation of Drinking Water

United States

The U.S. EPA's Office of Groundwater and Drinking Water (OGWDW) plays a key role with respect to drinking water in the U.S.A. Its mission is, "OGWDW, together with states, tribes, and other partners, will protect public health by ensuring safe drinking water and protecting ground water" (U.S. EPA 1999f). The information that follows is taken from the OGWDW, and its web site at http://www.epa.gov/OGWDW/. This web site provides detailed information on the nation's drinking water, including drinking water and health, drinking water standards and local drinking water information.

The U.S. EPA has established legally enforceable standards for public water systems called National Primary Drinking Water Regulations (NPDWR). These standards are used to protect the quality of drinking water by limiting levels of contaminants in public water systems that can adversely affect public health (Federal Register 1998). Public water systems are required to monitor drinking water for a host of contaminants to ensure consumer safety. Frequency of monitoring in the U.S. is dependent on the type of system, whether the source water is surface or groundwater, the type of contaminant, whether or not a contaminant has been previously detected or has exceeded the standard, and the number of people served by the public water system.

Currently, the U.S. EPA does not regulate aluminum under its drinking water program but has a secondary, non enforceable standard of 50-200 μg/l (this number is based on organoleptic properties). The U.S. EPA is working to determine if aluminum is of health concern and has placed aluminum on its Contaminated Candidates List (CCL). This list is the source of priority contaminants for the Agency's drinking water program. Priorities for drinking water research, occurrence monitoring, guidance development, including the development of health advisories will be drawn from the CCL. The CCL also serves as the list of contaminants from which the Agency will decide whether of not to regulate specific contaminants.

The U.S. EPA requires public water systems to be monitored for bacteriological, inorganic, organic and radiological contaminants. Monitoring of drinking water includes physical and chemical characteristics of the water, as well as analysis for contaminants resulting from natural sources or human activities.

Information on local water quality is available from several sources, including the state public health department and local water supplier. To inform the public of the results of the chemical analyses of drinking water and to demonstrate a commitment to protect human health, the U.S. EPA requires each community water system to generate an annual Consumer Confidence Report that is made available to all residents receiving water from that water system. Consumer Confidence Reports provide information about the source of water used, its susceptibility to contaminants where a source water assessment has been completed, the levels of contaminants detected in the water, the likely source(s) of contaminants, and potential health effects of any contaminant detected above that specific Maximum Contaminant Level (MCL). Copies of Consumer Confidence Reports exist at the state and county level, and can be reviewed to give an indication of overall quality of treated surface water and groundwater, and the condition of the drinking water service.

Each state also has a department that regulates drinking water systems, and these agencies can also provide information about the local water supply and its quality. In addition, the U.S. EPA maintains a data base which contains information on individual ownership, locations, violations, and enforcement actions (U.S. EPA 1999a). Most state drinking water databases include system detection information.

Source water assessments - States are required to prepare source water assessments for all public water supply systems by May, 2003. An assessment must contain - 1) designation of a source water area, 2) identification of the contaminants of concern to the users of the water supply, and 3) locations of potential contamination sources to the extent this is practical.

Wellhead Protection - Public water suppliers will be required to prepare and implement wellhead protection plans under provisions of Minnesota's wellhead protection rule. The goal is to have all community and nontransient, noncommunity water supplies that have vulnerable wells phased into the wellhead protection program by May, 2003. Wellhead protection plans are voluntary in Michigan and in Wisconsin that are required for some types of public systems.

Surface Water Intakes - Michigan, Minnesota, and Wisconsin will promote the preparation and implementation of protection plans for water supply intakes on Lake Superior. A protocol has been developed for designating source water areas in the Great Lakes. These efforts have great potential to be coordinated with LaMP activities.

Canada/Ontario

In Canada, the Federal Department of Health (Health Canada) establishes, in collaboration with the provinces and territories, the *Guidelines for Canadian Drinking Water Quality* under the auspices of the Federal-Provincial Subcommittee on Drinking Water. The provinces and territories may then use these guidelines as a basis for establishing their own enforceable guidelines, objectives, or regulations. In Ontario, drinking water quality is addressed by the Ontario Drinking Water Objectives. There is no organized water quality monitoring program for private water supplies. However, the public water treatment plants are required to regularly monitor the finished water for chemical and microbiological quality as outlined in the Ontario Drinking Water Objectives. The Ontario Ministry of Environment's Drinking Water Surveillance Program (DWSP) monitors raw (incoming source water), treated (at the treatment plant after water has been treated), and distributed water (at the consumer's tap) at selected locations throughout the province for over 200 parameters. DWSP maintains a database of contaminant levels measured in raw, treated and distributed water from about one quarter of all municipal treatment plants in Ontario, representing about 85 percent of the population serviced by municipal water supplies (Health Canada 1998b).

5.1.1.4 Lake Superior Drinking Water Quality - Data

United States

Consumer Confidence Reports should eventually provide precise information on drinking water quality at community water systems. A review of the Consumer Confidence Reports for Lake Superior basin (reports reviewed are listed in the References section) indicate contaminants in the treated public drinking water supplies were all below federal standards for basin residents in Minnesota and Wisconsin in 1998, demonstrating good overall quality of treated drinking water. Water quality for private water systems is generally good based on available data and conversations with individuals working for agencies that assist those consumers or regulate private wells, but it is important to note that groundwater quality from private supply wells is variable within the basin due to well construction practices; naturally occurring contaminants such as arsenic, boron, chloride, mercury; and anthropogenic contaminants such as bacteria and nitrate (CDC 1994, MPCA 1999). A large portion of the residents that obtain their water from private wells also have on-site wastewater treatment systems. Data for Michigan public water systems and private drinking water supplies were not received in time for this draft.

A study evaluating septic systems conducted in 1991 and 1992 found a failure rate of fifty-five percent along the Minnesota shore of Lake Superior (WLSSD 1994). Tap water was also sampled and seven percent of the domestic wells failed to comply with Minnesota Department of Health Safe Drinking Water Standards due to coliform contamination. However, all of the drinking water samples were below the standard for nitrate.

During 1994, the U.S. Centers for Disease Control and Prevention and nine Midwest states, including Minnesota and Wisconsin, systematically sampled private wells throughout the upper

Midwest for total coliform bacteria, *E. coli*, nitrate, and atrazine (one well every 10 square miles). In Minnesota, 27.3 percent of private wells tested positive for total coliform bacteria, 4.5 percent showed fecal contamination (positive for *E. coli*), 5.8 percent exceeded 10 mg/l nitrate nitrogen, and 0.1 percent showed atrazine over 3 µg/l. In Wisconsin, 22.8 percent of private wells tested positive for total coliform bacteria, 2.6 percent showed fecal contamination (positive for *E. coli)*, 6.6 percent exceeded 10 mg/l nitrate nitrogen, and 0.2 percent showed atrazine over 3 µg/l.

In St. Louis County, Minnesota, approximately 2,000 private wells are tested each year for coliform bacteria and nitrate. It is estimated that 25- 40 percent of the wells tested will fail the Minnesota Department of Heath limits for bacteria or nitrate (Johnson 1999). Within the Lake Superior basin in Wisconsin, nitrate concentrations typically are low or near background levels because of a thick protective clay layer present in much of the basin. In those portions of the basin where permeable soils do exist, the low density of residential and farm populations have not caused excessive nitrate loading problems. Coliform can occur in some of the private wells in the area, but the coliform detects are more a reflection of water system type and installation deficiencies than the quality of the groundwater in the basin. The groundwater is typically free of coliform (Herrick 1999).

Canada/Ontario

Provincial and municipal agencies frequently monitor community water supplies, and information on the results of testing is usually available upon request. The Ontario Drinking Water Surveillance Program (DWSP) reports that of the 654,382 tests performed under DWSP in 1993- 1997, 99.98 percent met the health related drinking water objectives (OME 2000), demonstrating good overall quality of drinking water delivered by treatment plants. Contaminant monitoring from individual treatment plants provides more precise information on local drinking water quality. In addition, executive summaries of the performance of municipal water treatment facilities monitored under DWSP, for the years 1993-1995 and 1996 - 1997, can be accessed at DWSP's web site at http://www.ene.gov.on.ca/envision/dwsp/index96_97.htm (site specific reports are available through the Ministry of Environment's Public Information Centre at 1-800-565-4923 or 416 325-4000). In addition, some municipalities publish their own reports.

Health Canada's Great Lakes Health Effects Program has published graphic summaries of levels of seven selected chemicals (aluminum, atrazine+metabolites, lead, mercury, total nitrates, total trihalomethanes, and tritium) chosen as indicators of the chemical quality of municipally treated drinking water drawn from the Great Lakes, other surface waters, and groundwater (Health Canada 1998b). The summaries used DWSP data from 1988 to 1995. Drinking water treatment plants were grouped by individual Great Lake basin, including Lake Superior, and were further categorized into Lake Superior surface water, other surface water sources within Lake Superior basin, and groundwater within Lake Superior basin. These summary figures show that average contaminant levels for Lake Superior are very low. With the exception of aluminum, average levels of contaminants in the assessment are below drinking water guidelines, and most show relatively stable or declining trends. For aluminum, the Federal-Provincial Subcommittee on Drinking Water has established an operational guideline for aluminum, which is the same operational guideline of 100 µg/L for aluminum as set by Ontario, and treatment plants are working on optimizing their treatment processes to reduce levels of aluminum in their finished water (Health Canada 1998b).

5.1.1.5 Needs for Future Research

Since 1971, CDC and the U.S. EPA have maintained a collaborative surveillance system for collecting and periodical reporting of data that relate to occurrences and causes of waterborne disease outbreaks. Public education efforts should include educating the public on what the drinking water guideline values mean, eg. is it safe to drink the water if levels are above the guideline?

There is a need for a mechanism to collect data on the incidences of diseases from drinking water, and a need for the public dissemination of this information. At present, there is no active mechanism in the Great Lakes basin for the collection of data and evaluation of incidences of waterborne disease from drinking water. In Ontario, the regional public Health Units are currently the principal sources of information on infectious diseases (Health Canada 1998f). The Minnesota Department of Health collects information on waterborne disease outbreaks in Minnesota. The U.S. Centers for Disease Control also collects this type of data, but not every State provides reports. An active waterborne disease surveillance system, where this information is required to be submitted on an ongoing basis, would have many benefits, including a better understanding of the current status and factors associated with waterborne disease (CPHA 1995).

Data on raw water levels or even finished water for many contaminants is not always available (and some are only available in paper format). Data is just beginning to be put in electronic databases.

Raw water intake monitoring is the most cost effective, and is relevant to multiple users. This data can be can be used by state ambient surface water monitoring and assessment programs, state source water assessment and protection programs, state public water supply supervision programs, and water treatment plant operators.

Water chemistry data collected at drinking water intakes should be determined case-by-case, and include data on contaminants for which Maximum Contaminant Levels (MCLs) have been established under the National Primary Drinking Water Regulations (NPDWR), and for some of the contaminants for which treatment techniques have been established under the NPDWRs.

Microbiological and turbidity monitoring should be included in the monitoring program. Because these contaminants pose an acute health risk, treatment techniques are required no matter what the quality of the source water with respect to these contaminants, and that under no circumstances would a Total Maximum Daily Load (TMDL) developed under Section 303(d) of the Clean Water Act, and/or a source water protection program (SWPP) obviate the need for continuous treatment. However, the TMDL and/or a SWPP can help reduce the burden of treatment. Excessive turbidity can interfere with disinfection, contribute significantly to drinking water treatment costs, and overwhelm filtration with break through of protozoan pathogens to finished drinking water.

Total organic carbon (TOC), a precursor for the production of disinfectant byproducts, should be monitored where nutrient enrichment causes algae blooms in source water.

State Public Water Supply Supervision Programs currently have monitoring data on treated drinking water. Because small public water systems and private well owners are not required to regularly test for most chemical contaminants, data on such supplies have largely been limited to special studies, and are therefore incomplete. More information is also needed on the incidence of waterborne diseases from public versus private sources.

Very little data exist on taste and odour problems. Information is primarily anecdotal, although Ontario’s Drinking Water Surveillance Program does collect data for geosmin and methyl isoborneol at selected locations, and many individual plants also have data.

People who live in an area that is served by a public water system probably don’t need any other form of water treatment. Some people choose to install point-of-use devices (example activated carbon filters) to remove chemicals and improve the taste and odour of untreated water. It is important to be aware, however, that the manufacture and sale of water treatment devices for home use is currently unregulated in Canada and the U.S., although their devices are tested and registered by trade groups such as the Water Quality Association and the National Sanitation Foundation. Also, such equipment must be carefully maintained. Poorly maintained systems can become breeding grounds for bacteria and other contaminants.

5.1.1.6 Conclusions

Outbreaks of illness related to the use of drinking water are rare and the populations affected are small. The drinking water in the Lake Superior basin is of good quality. However, continuing efforts must be made to inform health professionals and the public of the results of analyses of drinking water.

Monitoring, and corrective measures to reduce and eliminate levels of contaminants in treated water are essential components in assuring the safety of drinking water supplies. Ultimately, source water protection is the key to maintaining the good quality of drinking water supplies.

Agencies (U.S. EPA, Health Canada, state, provincial and municipal agencies) are involved in a range of projects and initiatives to continually improve the protection of drinking water, and they are described in the LaMP 2000 Action Matrix as well as on the agency websites identified in Section 5.4 of this Chapter.

5.1.2 Environmental Contaminants in Lake Superior Basin Recreational Water

The Great Lakes are an important resource for recreation, including activities such as swimming and sailboarding which 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 1998b, WHO 1998). Chemical pollutants may also pose health risks, but exposure to disease-causing microorganisms from sources such as untreated or poorly treated sewage is a greater risk (Health Canada 1999b).

5.1.2.1 Microbial Contaminants in Recreational Water

Many sources or conditions can contribute to microbiological contamination, including heavy rains that may cause combined or sanitary sewers to overflow (CSO or SSO) B Coliform densities have been observed to increase dramatically after periods of heavy rainfall (Whitman and others 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 of contamination. Storm water runoff in rural and wilderness area watersheds can increase densities of fecal streptococci and fecal coliforms as well (Whitman and others 1995). Other contaminant sources include infected bathers/swimmers; direct discharges of sewage eg. from recreational and commercial vessels; and malfunctioning private systems -- eg. cottages, resorts (Health Canada 1998b, Whitman and others 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 1998b, WHO 1998, Prüss 1998). Consequently, one of the Specific Objectives of the Great Lakes Water Quality Agreement is that "recreational waters should be substantially free from bacteria, fungi, and viruses that may produce enteric disorders or eye, ear, nose, throat and skin infections or other human diseases and infections" (IJC 1987).

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 1985a and 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).

Despite these studies, there are challenges in establishing a clear relationship between recreational water exposure and disease outcomes. Less severe symptoms resulting from exposure to micro-organisms are not usually reported , which makes statistics on cases related to recreational water exposure difficult to determine. In addition, the implicated body of water is not often tested for the responsible organism and when it is tested the organism is not usually recovered from the water. With the exception of gastro-intestinal illness, a direct relationship between bacteriological quality of the water and symptoms has not been shown -- a causal relationship exists between gastrointestinal symptoms and recreational water quality as measured by indicator-bacteria concentration (WHO 1998). Therefore, research efforts are focussing on conducting epidemiological studies to better establish the relationships between diseases and the presence of microorganisms in the water (Health Canada 1997, Health Canada 1998b, U.S. EPA 1999h).

5.1.2.2 Chemical Contaminants in Recreational Water

Chemical contaminants such as polycyclic aromatic hydrocarbons (PAHs) have been identified as a possible concern for dermal (skin) exposure in recreational waters. Dermal exposure to contaminants such as PAHs in sediment may occur when people swim in the water or come into contact with suspended sediment particulates in the water. PAHs adsorbed to these particulates would adhere to the skin. Research is ongoing to evaluate potential health effects of this route of exposure, including skin rashes and the potential to cause systemic effects, such as cancer (Hussain and others 1998, Lake Erie LaMP 1999).

A lifetime risk assessment from dermal exposure to PAHs in the St. Mary's River (Ontario, Canada) indicates that a lifetime health risk of skin cancer was well below the negligible risk range at inshore locations, but that some upstream sites had risk values higher than the negligible risk range and this may be cause for some concern. Strategies to reduce risk were developed with communities where the risk of exposure to PAH from recreational water use was increased. A key risk reduction recommendation was to take a bath or shower within 24 hours after a swim, thereby removing virtually all of the PAHs on the skin (Hussain and others 1998). Other sites in the Lake Superior basin where there are concerns about dermal contact with PAHs through swimming or wading include: two sites that are part of the St Louis River Area of Concern - Stryker Bay (part of the Interlake Superfund site in Duluth, Minnesota) and Hog Island inlet of Superior Bay in Superior Wisconsin; and a section of the Ashland, Wisconsin waterfront -- due to contamination from the Ashland coal tar site (Personal correspondence with Nancy Larson WI DNR 2000).

5.1.2.3 Protecting Public Health

Annex 2 of the Great Lakes Water Quality Agreement lists "beach closings" as an impairment of beneficial use related to recreational waters (IJC 1987). According to the International Joint Commission, a beach closing impairment occurs "when waters, which are commonly used for total body contact or partial body contact recreation, exceed standards, objectives or guidelines for such use" (IJC 1989).

For chemical contaminants in recreational water, some jurisdictions may issue human contact advisories to indicate that it is not safe to go into the water in these areas because of concern for exposure to specific chemicals (Lake Erie LaMP 1999).

For microbial contaminants, Federal, State and Provincial recreational water quality guidelines recommend bacterial levels below which the risk of human illness is considered to be minimal. In the U.S., states, territories, and Indian tribes set water quality standards for waters within their jurisdictions. The water quality standards program is administered by the U.S. EPA, which is mandated by Congress to provide water quality criteria recommendations, approve state-adopted standards for interstate waters, evaluate adherence to the standards, and oversee enforcement of standards compliance. Guidance for the development of standards by individual states, tribes, and territories is contained in the EPA documents Water Quality Standards Handbook, Second Edition (U.S. EPA 1983) and Ambient Water Quality Criteria for Bacteria (U.S. EPA 1986). Bacteriological water quality standards for each U.S. State are outlined on the U.S. EPA's web site at http://www.epa.gov/OST/beaches/local/sum2.html. The tables on this web site contain updated information on the bacterial water quality standards that have been adopted by states, territories, and tribes to protect human health from waterborne diseases within their jurisdictions. (U.S. EPA 1998j).

Canada

In Canada, regulations on recreational water quality are a provincial and territorial responsibility. Health Canada worked with officials in these areas to develop and publish national guidelines for recreational water quality. The *Guidelines for Canadian Recreational Water Quality* are available from Health Canada, and are also on Health Canada's website at http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/recreational_water.htm. These guidelines help to ensure that recreational waters are as free as possible from microbiological, physical and chemical hazards. To determine the risk of disease, the guidelines recommend conducting an environmental health assessment or sanitary survey at the beginning of each bathing season. (Health Canada 1999b).

For public beaches, the regional Public Health Units/Health Departments monitor beach water quality. When contaminant indicator levels in the bathing beach water reach levels that are considered to pose a risk to health, public beaches may be posted with a sign warning bathers of these potential health risks. The primary tool used at present to evaluate beach water quality is the measurement of indicator organisms which estimate the level of fecal contamination of the water. The two indicator organisms most commonly used are fecal coliforms (coliforms are bacteria found in the intestinal tract of humans and animals; their presence in ambient water indicates fecal pollution and the potential presence of pathogens) and Escherichia coli (*E. coli*) (the fecal coliform organism exclusively found in human and animal feces). High levels of these organisms in recreational water are indicative of fecal contamination and the possible presence of intestinal disease-causing organisms. (Health Canada 1998b, Lake Erie LaMP 1999, WHO 1998).

In Ontario, the local Public Health Units monitor the water quality at public beaches on a regular basis throughout the bathing season, following the sampling and posting criteria detailed in the "Beach Management Protocol, Water Quality Program" (Ontario Ministry of Health 1992). In Ontario, *E. coli* is used as the indicator of recreational water quality (Ontario changed its guideline from fecal coliform to *E. coli* in 1992). Local health authorities are also responsible for investigating any illnesses resulting from bathing at public beaches. If the number of reported problems is unusually high the authorities will either increase their monitoring of water quality or temporarily close the beach to the public. In some cases, such as an outbreak of illness, tests for disease-causing organisms, like viruses, are conducted. (Health Canada 1999b, Lake Erie LaMP 1999).

United States

The U.S. EPA uses *E. coli* or enteroccocci as indicators of recreational water quality, and there is an increasing move by States toward their use, especially *E. coli*, since it is better correlated with gastrointestinal illness than fecal coliforms, and elevated fecal coliform counts do not always indicate a human health hazard (fecal coliforms include many species which are not exclusively found in human and animal wastes). (U.S. EPA 1999c, Bartram and Rees 2000).

In the U.S., a number of initiatives have recently been developed to specifically address recreational water quality. The U.S. EPA established the BEACH Program in 1997 "to significantly reduce the risk of waterborne illness at the nation's beaches and recreational waters through improvements in recreational water protection programs, risk communication, and scientific advances" (U.S. EPA 1999c).

As a result of the Beach Program being instituted, U.S. EPA developed the *Action Plan for Beaches and Recreational Waters* ("BEACH Action Plan", EPA/600/R-98/079), a multi-year strategy for reducing the risks of waterborne illness to recreational water users. (U.S. EPA 1999e). The BEACH Action Plan describes EPA's actions to improve and assist in state, tribal, and local implementation of recreational water monitoring and public notification programs. In addition, the U.S. Federal Clean Water Action Plan was announced in 1998, and describes a series of actions designed to strengthen core clean water programs carried out by a number of U.S. governmental agencies (U.S. EPA 1998).

5.1.2.4 Lake Superior Recreational Water Quality Data

A determination of human health risk from swimming at Lake Superior beaches which exceed water quality standards has not been made. However, information on the bacteriologic condition of beaches and frequency of beach postings is available from a number of sources. At present three of the Lake Superior AOCs list beach closings as a beneficial use impairment in their Remedial Action Plans (St. Louis River, St. Marys River and Thunder Bay; for more information on Lake Superior AOCs go to: http://www.cciw.ca/glimr/raps/intro.html).

Ontario Public Health Units, who are responsible for the monitoring of Ontario public beaches, collect, document and house detailed data on the beaches they monitor, including: a beach pollution survey or similar report, either historical, or done at the beginning of the bathing season, to include information on potential sources of contamination impacting on the bathing beach area; *E. coli* data ; beach postings data; and additional information on beach conditions on the day of monitoring (rain, winds, temperature, visibility, etc.) (Lake Erie LaMP 1999). The Ontario Ministry of Environment has a historic database that identifies total annual beach postings for public beaches in Ontario from 1988 onward (OMEE 1995).

For U.S. States, some information on the current condition of beaches and potential population affected is available through the U.S. EPA's BEACH Watch Program, as well as the Natural Resources Defense Council's Testing the Waters - 1999: A Guide to Water Quality at Vacation Beaches (NRDC 1999). Under the U.S. EPA BEACH Program, the first National Health Protection Survey of Beaches, conducted in 1997, focused on the collection of beach-specific information from coastal and Great Lakes States. Data from the second annual Survey, conducted in the spring of 1999, can now be accessed on the BEACH Program website at http://www.epa.gov/OST/beaches/ (U.S. EPA 1999e). States compile information regarding exceedances of bacteria standards as part of their efforts to develop "non-attainment" lists required by section 303(d) of the federal Clean Water Act. States are also required to report incidences of beach closings every two years as part of their water quality reports to the U.S. EPA required by section 305(b) of the Clean Water Act.

When reviewing the data, it is important to note that, despite the potential risks to the public from gastrointestinal illness and other infections, water quality monitoring programs vary widely at the state and local levels. Different states and jurisdictions monitor for different indicator organisms, and also have different criteria and standards for postings or advisories. In addition, frequency of monitoring bacterial contamination at public beaches is highly variable around the lake. Because of this variability, it is difficult, and potentially misleading, to compare water quality between jurisdictions or summarize data for all beaches. Even within a beach, variability in the data from year to year may result from the process of monitoring and variations in reporting, and may not be solely attributable to actual increases or decreases in levels of microbial contaminants. It is important to keep these limitations in mind when looking at the recreational water quality data (Health Canada 1998b, U.S. EPA 1998a, NRDC 1999).

The limitations in the ability to compare frequency of exceedances of microbiological guidelines has posed a challenge for the development of a lakewide indicator to evaluate trends in recreational water quality. Traditionally, frequency of beach postings has been used as an indicator of recreational water quality, but the use of beach postings data as an indicator of trends in water quality also has limitations. Microbial exceedances are still a better measure of actual health risk related to recreational water quality, and recent discussions are leaning toward developing an indicator that uses microbial monitoring data, supplemented by beach postings data. This combination will give a much more informative picture about microbial quality of recreational use waters (IJC IITF Swimmability Workshop, October 1999).

Health Canada has developed a preliminary indicator of recreational water quality in the Canadian Great Lakes basin, based on measurements of the number of *E. coli* at selected Ontario public beaches. This indicator is published in "*Health- Related Indicators for the Great Lakes Basin Population: Numbers 1-20*" (Health Canada 1998b) For the Lake Superior basin, this indicator includes data for Thunder Bay public beaches monitored by the Thunder Bay District Health Unit.

5.1.2.5 Needs for the Future

There is a need to better understand the relationships between diseases and the presence of microorganisms in the water, and this type of research is ongoing. At present, there is no active mechanism in the Great lakes basin for the investigation of incidences, if any, of waterborne disease due to recreational water use. The present system is one in which health units/ departments and other entities submit available information on a voluntary basis. The development of an active waterborne disease surveillance system would be useful toward informed decision making, increased responsiveness, and better understanding of factors associated with waterborne disease (CPHA 1995, Health Canada 1998f).

Viruses and protozoa, although a concern in recreational waters, are difficult to isolate and quantify at present, and feasible measurement techniques have yet to be developed for these pathogens. (Health Canada 1998b,U.S. EPA 1999d). Efforts are ongoing to develop new and better ways to assess both viral and bacterial contamination in recreational waters. These include the development of tests to more rapidly evaluate water quality before exposure occurs, which would in turn allow improved public health protection by prompt beach postings and by alerting the public of a potential health risk (Health Canada 1998b, Lake Erie LaMP 1999). Rapid analytical methods are needed to identify risk before exposure takes place. Current microbial testing methods for indication of possible pathogen presence require 24 to 48 hours of incubation before problems can be detected, leaving ample time for exposure to occur (U.S. EPA 1998a).

The effects of CSO and SSO discharges on recreational waters need to be quantified. EPA is proposed to conduct research to determine pathogen occurrence and indicator relationships associated with wet weather flows (U.S. EPA 1998a).

Playing/walking in the shallow interstitial (sand/water interface) water of beaches is a popular activity for all ages, particularly for children, who play with water toys as well as splash extensively in these shallow waters. The public health implication of bacteria, viruses, and protozoa in shallow beach water is unknown. It would be of great public health benefit to gather data on types, concentrations, survival patterns and other relevant information on pathogens in the interstitial waters of Great Lakes beaches, to better understand whether there is a potential for environmental/health effects in these waters. Some investigatory work is currently ongoing for this issue. (Whitman 1995, Springthorpe 1999, Palmateer 1999).

Water can also be inhaled as a fine aerosol during vigorous recreational water activity, and there is an interest in better understanding the health risks associated with inhaling contaminated aerosols generated by splashing in the water, water-skiing, and other recreational water activities. (Health Canada 1997; Springthorpe 1999).

5.1.2.6 Conclusions

Although there have been sporadic outbreaks of illness related to the use of recreational water, it must be emphasized that the populations affected are probably small compared to the total population of the Great Lakes basin, and even compared to the total number of recreational bathers (Health Canada 1998b).

Agencies (U.S. EPA, Health Canada, state, provincial and municipal agencies) are involved in a range of projects and initiatives to continually improve the protection of recreational waters, and they are described in the LaMP 2000 Action Summary (Figure 5-1) as well as on the agency websites identified in Section 5.6 of this chapter.

5.1.3 Air Pollution - Environmental Contaminants in the Air We Breathe

Improvement and protection of air quality in the Lake Superior basin and definition of the consequences of long range transport are one of the ecosystem objectives developed for the Lake Superior LaMP (See Table 5-1). The Lake Superior Human Health Committee plans on addressing these issues to a greater extent in future LaMP documents. The following is a brief list of resources that can be accessed for further information on air related issues.

For the United States the Clean Air Act implemented by the U.S. EPA and State Agencies are 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.org).

In Canada, Health Canada conducts air pollution health effects research, risk assessments and exposure guidelines creation through programs such as the Air Pollution Health Effects Research Program in its Environmental Health Directorate (http://www.hc-sc.gc.ca/ehp/ehd/bch/air_quality.htm), in addition the Province of Ontario has programs targeted at the protection of human from exposure to air pollution. (Soils/Sediments text from personal correspondence with Carl Herbrandson of Minnesota Department of Health 2000)

5.1.4 Environmental Contaminants in Soils/Sediments and Related Human Health Issues (Hebrandson 2000)

Just as soils are the ultimate fate of persistent chemicals in the air, sediments are a sink for chemicals in aquatic systems. While plants grow in soils and form the base of the terrestrial food chain, benthic organisms, living in sediments, lacking cell walls, and containing high proportions of lipids and fats in cell membranes and other organelles, are the base of the aquatic food chain. Thus, sediments are not merely a sink for hazardous compounds, but also a source of lipophilic compounds to the aquatic food chain and, potentially, to humans and other fish eaters.

It has become clear that the accumulation into the food chain of PBT chemicals, such as PCBs, dioxins and dibenzofurans, and mercury (as methylmercury), is not solely dependent on their concentration in sediments. Characteristics of the sediment such as organic content, microbial environment, pH, redox conditions, and presence of sulfates and sulfides can all affect the potential for PBT chemicals to be bioaccumulated. Furthermore, sediment reactions are typically characterized and studied as static systems. In the environment, though, reactions which occur may be affected by groundwater flow. Groundwater flow may cause water of groundwater or surface water origin to regularly replace porewater. Therefore, equilibriums between reactants and products may not be achieved, and production and/or transport of some compounds might occur at much higher rates than previously proposed. This is the basis of suppositions which may explain the continuing elevated levels of PCBs in fish in the Hudson River and may also explain some of the variability in methyl mercury production and ultimate accumulation in fish. Without a better understanding of the chemical reactions and interactions in this transition zone between groundwater and surface water, quantitative risk assessment of the potential effects of PBT contaminated sediments will remain associated with large uncertainties.

As mentioned above, there are numerous hazardous chemicals which have greater health impacts on ecological communities than humans when found at elevated levels in sediments. These include some metals, lead for example, and some organic compounds, such as PAHs.

Lead is an element which is often found at elevated levels in soil and dust in the terrestrial environment, but it can also be found at high concentrations in sediment. In soil, 400 ppm lead is of concern due to the potential for children to accidentally ingest quantities which could increase blood lead concentrations to levels which have been shown to impact development. Sediments with similar concentrations, while being at least as toxic as soil lead (methylation in sediment may increase the bioavailability - GI tract uptake - of lead and thereby increase its potential toxicity to animals) is not as accessible as bare soil, and therefore, ingestion of quantities over significant periods of time are unlikely. On the other hand, benthic organisms are much more susceptible to lead than are plants, showing effects at around 31 ppm, and therefore sediment criteria are often set below this level.

PAHs are toxic organic compounds which are persistent in the environment. They have been shown to cause cancer in humans and other animals. When found in sediments they may adversely affect benthic organisms, but human exposures are usually limited. Non-cancerous effects on waders or swimmers may include irritation of the skin, but as mentioned above, this effect would be expected to occur at concentrations significantly greater than those found to impact invertebrate populations. PAHs may also be accumulated by some aquatic organisms, typically those that are unable to metabolize PAHs. Fish and other vertebrates, though, are able to metabolize PAHs and therefore do not generally accumulate them. As a result, ingestion of fish exposed to reasonably high levels of PAHs usually does not significantly increase PAH consumption for humans or wildlife. It is possible that PAHs may accumulate in other aquatic species which are eaten by people, such as clams, mussels, and snails, but these animals are not typically harvested from waterbodies in the Great Lakes basin.

5.1.4.1 Needs for Future Work

While there are large databases containing information on the toxicity of various contaminants to aquatic organisms, most of the information was gathered in laboratory studies which do not accurately reflect conditions found in the environment. As a result our understanding of what takes place in the environment, the hydro- and geochemistry of contaminants and the toxicity, biotrophic, and ecological effects of mixtures, may be somewhat limited. Therefore, any analysis of the effects of sediment contamination on humans is usually restricted to qualitative evaluation and analysis of uncertainties.

5.1.5 Persistent Bioaccumulative Toxic Chemicals in Food/Fish

5.1.5.1 General Population Exposures to PBT Chemicals

People in the Great Lakes basin get their food from a global market, this general market basket diet contributes to over 95 percent of their intake of PBT chemicals. Exposure assessments from all sources (air, water, food and soil) were completed for the Canadian Great Lakes basin general population, for eleven PBT chemicals, including the nine chemicals designated for zero discharge for Lake Superior. 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 persistent toxic substances from Great Lakes sources, such as high consumers of sport fish. At present six of the Lake Superior AOCs list restrictions on fish and wildlife consumption as a beneficial use impairment in their Remedial Action Plans (St. Louis River, Torch Lake, Deer Lake, St. Mary’s River, Peninsula Bay and Thunder Bay; for more information on Lake Superior AOCs go to: http://www.cciw.ca/glimr/raps/intro.html)

5.1.5.2 PBT Chemicals in Human Breast Milk

In Canadian populations, Craan and Haines (1998) reported a downward trend from 1967 to 1992 in the concentrations of organochlorine pesticides and PCBs in human breast milk. A similar decline could be expected of organochlorine concentrations in human breast milk in the Great Lakes basin. (Craan and Haines 1998).

Nonetheless, trace levels of PCBs and other PBT chemicals are found in breast milk of the general population. Very little is known about the effects of exposure of infants to moderately high levels of organochlorines during the breast-feeding period. Jacobson and others (1992) did not find an association between breast-feeding and developmental deficits in his Michigan fish consumers study (Van Oostdam and others 1999). Rogan and others (1991) in reporting on the North Carolina Breast Milk and Formula Project, saw no evidence of adverse effects from exposure to PCBs or DDE through breastmilk, although they did report a subtle motor delay attributable to transplacental (in utero) exposure. Research is continuing into health risks of PBT chemical exposure from breast feeding and other exposure routes.

"There are many recognized advantages to breast-feeding to infants and to mothers, including improved nutrition, increased resistance to infection, protection against allergies, and better parent-child relationships. With full regard for the uncertainty over the toxic effects of organochlorines in human milk, the known benefits of breast-feeding are extensive and serve as a strong rationale for advising mothers to continue to breast-feed their newborns unless cautioned by their local health care worker to reduce or stop" (cited from Van Oostdam and others 1999).

5.1.5.3 PBT Chemicals in 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, polychlorinated biphenyls (PCBs), and toxaphene enter the aquatic environment and build up in the food chain of fish. The levels of the chemicals in fish from the Lake Superior 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. Therefore 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.

Many chemicals are present in surface waters at very low concentrations. Some of these chemicals can bioaccumulate in aquatic organisms via their diet and become concentrated at levels that are much higher than in the water itself. This is especially true for substances that do not break down readily in the environment i.e., persistent chemicals - like toxaphene and PCBs. In the process of feeding, these persistent chemicals are collected. Small fish and zooplankton eat large quantities of phytoplankton. In doing so, any toxic chemicals accumulated by the phytoplankton are further concentrated in the bodies of the animals that eat them. This is repeated at each step in the food chain. The concentration of some chemicals 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. Although bioaccumulative chemicals are present in other food, the concentrations that build up in fish, due to the number of steps in the food chain of fish, are much higher than in other food. Figure 5-2 shows 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 (Government of Canada and U.S. EPA 1995).

Figure 5-2 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.

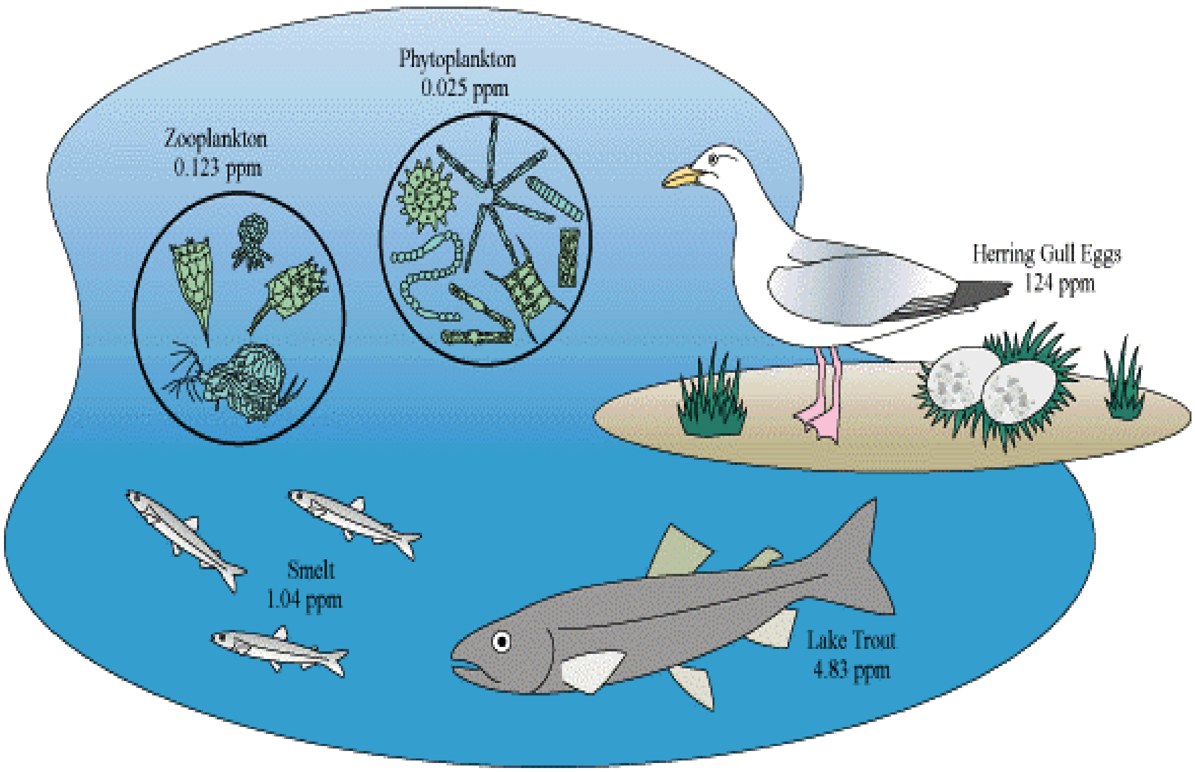

Figure 5-2. Persistent Organic Chemicals, such as PCBs, Bioaccumulate

Figure Taken from: "The Great Lakes: An Environmental Atlas and Resource Book," (Government of Canada and U.S. EPA 1995).

All food, including fish, contain environmental contaminants. Federal government agencies restrict the sale of fish based on environmental contaminants in the edible portion. When setting the acceptable level of a contaminant in commercial fish, federal governments take into account several factors in addition to potential health effects including: assumptions about how much fish people eat, the species consumed, where the fish come from, and economic considerations.

State and provincial governments provide information to consumers regarding consumption of sport-caught fish. This information is not regulatory - its guidance, or advice. Although some states use the Federal commercial-fish guidelines for the acceptable level of contaminants when giving advice for eating sport caught fish, consumption advice offered by most agencies is based on human health risk. This approach involves interpretation of studies of health effects from exposure to contaminants. Evidence for Potential Health Effects: Linking Environmental Exposure, Section 5.2, of this report summarizes the major studies of effects from exposure to PBT chemicals. Each state or province is responsible for developing fish advisories for protecting the public from pollutants in fish and tailoring this advice to meet the health needs of its citizens. As a result, the advice from state and provincial programs is sometimes different for the same lake and species within that lake.

The toxic endpoints used in risk assessments for calculating safe fish consumption levels are subtle (the effects are not easily recognizable or attributable to a particular exposure and that exposure does not cause immediate harm). Numbness of fingertips, dizziness, and the sensory loss that might occur from toxic exposures to methylmercury, might easily be attributed to getting old. Developmental problems resulting from in-utero exposure to PCBs are difficult to measure or even separate from confounding factors like smoking or alcohol consumption. The variability in response of individuals exposed to PBT chemicals dictates a more conservative approach, perhaps producing guidance that is over protective of a large portion of the population.

It is important that people are aware of contaminants in fish and the actions that can be taken to reduce exposure, particularly those people who are at greatest risk from those exposures from overexposure to contaminants found in fish. Exposure to detrimental levels of environmental contaminants can cause a variety of negative health effects. The precise level of contaminant exposure that is detrimental to an individual is going to vary with his/her age, sex, genetics, current physical condition, and previous exposure of that individual. Individuals within a population will vary in their sensitivities to environmental contaminants. It is not possible to determine *a priori* which individuals within a population are going to be most sensitive to contaminant exposure. Because governments need to protect sensitive individuals in the population, the advice governments provide may be over protective for some portion of the population.

While the average person in the Lake Superior basin may not be at risk of experiencing adverse health effects from exposure to contaminants through the consumption of fish, there are some people who are at risk. These include people who eat a lot of fish, regularly eat large predator fish, eat fish from highly contaminated waters, or eat a large amount of fish over a short period of time. In addition, the developing fetus and young children are at greater risk than adults.

Nursing women are generally given the same consumption advice as pregnant women and other women of child-bearing age. This advice is given because of the potential for another pregnancy. The benefits of breast feeding are well established, and research studies looking at effects in infants of mothers who consume large amounts of contaminated fish attribute health effects to *in utero* exposure to PBT chemicals rather than to maternal breast milk (Johnson and others 1998). In general, exposure to contaminants in fish can be reduced by:

- eating panfish rather than predator fish (panfish have lower concentrations of contaminants because they are lower on the food chain)
- eating smaller predator fish (smaller fish are generally younger and have had less time to build up contaminants)
- spacing meals out over time (some contaminants like mercury are eliminated by the human body)
- removing as much fat as possible when cleaning and cooking fish (organochlorine contaminants are stored in the fat, mercury is stored in the protein and so is not reduced by cooking and cleaning)

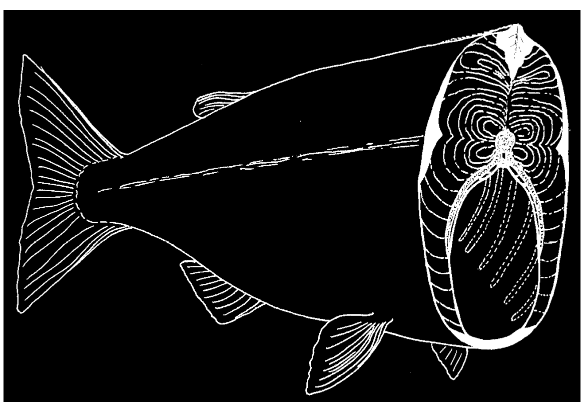

Figure 5-3 Wisconsin Sea Grant Fish Cleaning Diagram

5.1.5.4 Protecting Public Health

Fish Consumption Programs are well established in the Lake Superior basin. The states of Michigan, Minnesota and Wisconsin, the Province of Ontario, and many tribes in the basin have extensive fish contaminant monitoring programs and issue advice to their residents about how much fish and which fish are safe to eat. This advice ranges from recommendations to not eat any of a particular size of certain species from some waterbodies, to recommending that people can eat unlimited quantities of other species and sizes. Advice from these agencies to limit consumption of fish from Lake Superior is mainly due to levels of PCBs, mercury, chlordane, dioxin, and toxaphene in the fish.

Fish consumption advice for Lake Superior is communicated to the public in a variety of ways. The Province of Ontario, some tribes, and the three U.S. states that border Lake Superior publish annual or biannual information on waterbodies from which fish have been tested for contaminants and give specific consumption advice for these fish. Advisory information is also available in formats designed for particular populations such as factsheets translated into immigrant languages, low-literacy fact sheets, and brochures created to inform women of childbearing age of risks to the fetus. These booklets and brochures are available at no charge to the public and many are available on the Internet.

Advice to limit consumption of fish from inland lakes in the basin is generally based on the presence of mercury in these fish. Since mercury can be transported long distances in the atmosphere and then deposited in lakes, even fish in remote lakes far away from human activity can have mercury levels high enough to warrant consumption advice. Due to the presence of mercury in fish from virtually all inland lakes, the three states in the basin and the Province of Ontario, each issue advice to women of childbearing age to limit consumption of fish from inland lakes. The table below summarizes this advice. Due to mercury levels, Minnesota and Ontario also give advice to women of childbearing age regarding consumption of shark, swordfish, and tuna.

Table 5-2 Mercury-Based Consumption Advice for Childbearing Age Women and Children for Fish from Inland Lakes

State or Province	Type of Fish	Meal Frequency Advice
Michigan	any size predator fish and panfish over 9 inches in length	one meal per month
Minnesota[a]	panfish	one meal per week
	other fish less than 20 inches	one meal per month
	other fish greater than or equal to 20 inches	do not eat
Wisconsin	fish with 0.5 ppm or less mercury	one meal per month[b]
	fish with greater than 0.5 ppm mercury	do not eat[c]
Ontario	fish with 0.45 ppm or less mercury	four meals per month
	fish with greater than 0.45 ppm mercury	do not eat

a Advice shown in table is for women who eat fish all year round
b Applies to pregnant women only
c Applies to women of childbearing age and children under fifteen

There are many potential barriers to communication of fish consumption advice. People who fish a lot feel confident and familiar with the risks and may not be interested in hearing about the advisory or are skeptical of the concern because they have not seen any apparent effects. There may be barriers of literacy and access, such as with new immigrants. Economic barriers may exist for subsistence fishers. Cultural barriers also exist regarding choice of fish species, releasing fish, and cooking and cleaning practices.

Studies have shown that having an awareness of health advisories can be successful in changing fishing and fish consumption habits (Fiore and others 1989; Velicer and Knuth 1994). The communication programs in the Great Lakes generally target white, licensed anglers and may not be reaching other sensitive populations B minorities, immigrants and women of child bearing age (Tilden and others 1997, Velicer and Knuth 1994). Written information (i.e., regulation booklets and advisory brochures) is circulated by the government and the fishing industry to licensed anglers, and these sources of information appear to be effective in reducing consumption of contaminated fish. For example, Fitzgerald and coworkers (1999) found that 97 percent of the men in their study were aware of fish advisories and two-thirds of these men had reduced their fish consumption. This reduction in fish consumption was due to public health intervention strategies such as risk communication along with the use of fish advisories. More recent efforts have been directed toward groups with less awareness of health advisories such as women of childbearing age, minorities, and other frequent fish consumers (Knuth 1995, Tilden and others 1997).

5.1.5.5 Needs for the Future

Fish advisories are issued because health officials assume that some people eat more fish than recommended in the advisory guidelines. U.S. EPA estimated that 7 percent of women of childbearing age and 25 percent of children in the U.S. are exposed to more mercury in their diet from fish consumption than is considered safe (U.S. EPA 1997a). Fish consumption advice is communicated through distribution of printed materials, press releases, public presentations, local public health agencies, and health care providers. There has been minimal evaluation of the effectiveness of these communications both in the advice reaching the at risk populations and in the successful communication of the message. Studies of fish advisory awareness in the Great Lakes basin generally report an awareness of approximately 40 to 50 percent among residents.

Wildlife: PBT chemicals are also a concern for consumption of wildlife, particularly fish-eating waterfowl. In addition there are concerns with respect to lead exposure when consuming game birds harvested with lead shot shells. Some research is currently available looking at PBT chemicals and lead shot exposure in wildlife. Although not discussed in this chapter, subsequent LaMP reports will address this issue.

Surveillance: There is a need for surveillance to evaluate how much fish people eat and carry out biomonitoring to determine actual tissue levels, particularly within sensitive populations (Great Lakes Sport Fish Advisory Task Force 1999). Surveys have been carried out in the Lake Michigan and Lake Ontario basins. However Lake Superior basin residents may have different fish eating habits than residents from these basins. For example, differences exist in the fishery itself and in the charter industry. Some bio-monitoring data will be available within the next year for MN and WI residents from the U.S. EPA project summarized above. However, at this time it is not known how many of the participants live in the Lake Superior basin. Mercury analysis of participants hair in the EERC ND/MN Fish Consumption Survey Project could be added with additional source of funding. A limited number of hair analysis is currently planned for in this project.

<u>"Can we eat the fish?" Indicator:</u> The various long-term fish contaminant monitoring data sets that have been assembled by several jurisdictions for different purposes need to be more effectively utilized. Relationships need to be developed that allow for comparison of existing data from the various sampling programs (Whittle 1999).

<u>Awareness:</u> Fish advisory awareness among Lake Superior basin residents needs to be increased. Tilden and coworkers (1997) conducted a population-based survey of fish consumption within the eight Great Lakes states. The study results demonstrated that almost 50 percent of the Great Lakes fish consumers had an awareness of the health advisories. Of the 50 percent, approximately 60 percent of the males were aware of the advisories with less than 40 percent of the females having an awareness. These findings emphasize the importance of targeting health advisories to sensitive groups such as women of reproductive age. The sensitive groups include women of childbearing age and their fetuses and infants, the elderly, sports anglers, and minorities. (MN DNR survey 1998).

<u>Evaluation:</u> The evaluation of health advisories is an integral part of determining the effectiveness of a program. The U.S. EPA's Guidance document for fish advisories (EPA 1995) makes recommendations for evaluating the risk communication efforts for fish advisories and provides a step-by-step approach for conducting an evaluation of an existing program. Program evaluation is necessary to determine 1) if the health advisory is reaching the target population, 2) if it is being implemented properly, 3) if it is effective, 4) the cost, and 5) the cost relative to effectiveness (Windsor and others 1994).

<u>Benefits:</u> The benefits of eating fish need to be quantitatively incorporated into the risk assessment for fish consumption advice. Benefits are qualitatively taken into account by providing statements about the benefits in the published information (TERA 1999). U.S. EPA funded a project to develop a framework to incorporate benefits of fish consumption into state fish advisories (TERA 1999). At this point the framework is qualitative and is undergoing external peer review. Quantitative assessment of benefits of fish consumption relative to the risks from contaminants has been ranked as a high priority among U.S. states issuing fish advisories. The U.S. EPA project will identify research needs that are not currently funded.

5.1.5.6 Conclusions

Diet contributes over 95 percent 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. Because of the presence of PCBs, organochlorine insecticides, mercury, and other chemicals found in fish from the Lake Superior basin, fish advisories are issued that recommend restrictions on fish consumption, with tighter restrictions (in some cases to the point of complete elimination) of fish from the diet of pregnant women, women of childbearing age and children. In 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.

5.2 EVIDENCE FOR POTENTIAL HEALTH EFFECTS - THE WEIGHT OF EVIDENCE APPROACH TO LINKING ENVIRONMENTAL EXPOSURE

The following three subsections describe selected studies which 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 small sample sizes and the 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 effect. In addition, human studies looking at causal relationships between human exposure to environmental contaminants and adverse health outcomes are limited and the results uncertain. In addition, there are not that many human studies, and there are uncertainties around these studies. 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. Therefore, a weight of evidence approach is used, that is the overall evidence from wildlife studies, experimental animal studies, and human studies is considered. 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).

5.2.1 Wildlife Populations

Research over the past 25 years has shown that a variety of PBT chemicals 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 egg shell 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 and others 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 polyaromatic hydrocarbon compounds have also been detected in brown bullhead fish in the Great Lakes area (Baumann and others 1982).

Table 5-3 Effects of PBT Chemicals on Fish and Wildlife in the Great Lakes

Species	Population decrease	Effects on Reproduction	Eggshell thinning	Birth defects	Behavioral changes	Biochemical changes	Mortality
Mink	✓	✓	NA	NE	NE	NE	✓
Otter			NA	NE	NE	NE	S
Double-crested cormorant	✓	✓	✓	✓		✓	S
Black-crowned night heron	✓	✓	✓	✓		✓	S
Bald eagle	✓	✓	✓	NE		NE	NE
Herring gull		✓	✓	✓	✓	✓	✓
Ring-billed gull				✓		NE	✓
Caspian tern		T		✓	NE	NE	
Common tern		✓	✓	✓		✓	
Forster's tern		✓		✓	✓	✓	
Snapping turtle	NE	✓	NA	✓	NE	NE	NE
Lake trout		✓	NA			✓	
Brown bullhead			NA			✓	
White sucker			NA	✓		✓	

Source: U.S. EPA's National Water Quality Inventory: 1992 Report to Congress.

Notes:

NA = not applicable
NE = not examined
S = suspected

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 and others 1996). Table 5-3 summarizes the observations for the main categories of these adverse effects. These effects have not been seen in all species, in all locations, or in all years, but provide proof that such effects can occur when exposure is sufficient (Health Canada 1997).

5.2.2 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 higher chlorinated PCB mixtures (i.e., 60 percent 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 and others 1991, Sargent and others 1992). A General Electric Company sponsored study demonstrated the carcinogenicity of Aroclor-1016, Aroclor-1242, Aroclor-1254, and Aroclor-1260 in rats receiving dietary exposure to PCBs. As an example, liver tumors were observed in female rats, and thyroid cancers were reported in male rats (Brunner and others 1996).

A number of animal studies have demonstrated immune effects following exposure to PCBs (Arnold and others 1995, Tryphonas 1995, Ross and others 1996). In a laboratory study, harbor seals were administered a diet of Baltic sea herring contaminated with organochlorine compounds and other pollutants (Ross and others 1996). When compared with seals given a diet of relatively uncontaminated Atlantic Ocean fish, the seals ingesting the contaminated sea herring were found to have impaired natural killer cell activity and T-lymphocyte function.

Neurobehavioral effects have been seen in monkeys, exposed orally from birth to 20 weeks, to a PCB congener mixture representative of the PCB mixture found in the breast milk of Canadian women (Rice 1997). The monkeys were subsequently tested at 2.5 and 5 years of age, and found to have deficits in learning and difficulty in learning complex tasks when compared to controls.

Mercury: Long-term, high level animal ingestion exposure to mercury has been associated with cardiovascular (Arito and Takahashi 1991), developmental (Fuyuta and others 1978, 1979; Nolen and others 1972; Inouye and others 1985), gastrointestinal (Mitsumori and others 1990), immune (Ilback 1991), renal (Yasutake and others 1991, Magos and others 1985, Magos and Butler 1972, Fowler 1972), and reproductive effects (Burbacher and others 1988, Mitsumori and others 1990, Mohamed and others 1987). The studies also indicate that the nervous system is particularly sensitive to mercury exposure by ingestion (Fuyuta and others 1978; Inouye and Murakami 1975; Magos and others 1980 and 1985).

In addition, growth of kidney tumors has been reported in animals administered methylmercury in drinking water or diet for extended periods (Mitsumori and others 1981 and 1990). The U.S. EPA Mercury Study Report to Congress, Volume V: Health Effects of Mercury and Mercury Compounds, 1997, provides a good summary of methylmercury toxicity.

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 nonlethal 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 and others 1978), and a decline in blood cells (Kociba and others 1978). Dermal effects in animals (e.g., hair loss, chloracne) have also been reported by ingestion exposure (Mc Connell and others 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 and others 1983, Gray and Ostby 1995, Tryphonas 1995, Schantz and Bowman 1989, Schantz and others 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 and others 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 and others 1995, De Vito and others 1995, Henshel and others 1995b, Henshel and Martin 1995a, Vo and others 1993).

5.2.3 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. Human epidemiological studies are limited in their ability to separate health effects attributable to contaminant exposures from those related to other known health factors like smoking, alcohol intake and general health status. In addition, exposure to contaminants from Great Lakes fish is dependent upon the amount eaten and species consumed. For the Lake Superior basin, there is little information available on exposure levels, body burdens and health effects for people who consume fish in and around Lake Superior. Consequently, results from studies in other areas of the Great Lakes basin are used to assess risks and benefits of eating Great Lakes fish.

5.2.3.1 Exposure Studies

Fish species residing in waters contaminated with lipophilic pollutants (i.e., fat-soluble pollutants as PCBs) bioaccumulate these contaminants and become a further source of contamination for larger, predator fish (e.g., sport caught trout and salmon) (Humphrey 1988). This process results in a biomagnification or increase in the levels of contaminants in the predator fish which may subsequently be consumed by humans. Fish consumption has been shown to be a major pathway of human exposure to persistent toxic substances such as PCBs (Birmingham and others 1989; Fitzgerald and others 1996; Humphrey 1983; Newhook 1988), exceeding exposures from land, air, or water sources (Humphrey 1988).

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 Lake Michigan fisheaters, Humphrey (1988) discovered that sport anglers who regularly consumed Great Lakes salmon and trout (consumption rate of $\geq$ 24 pounds/year [or 11 kg/year]) had median serum PCB levels approximately 4 times higher (56 ppb) than those who consumed no Lake Michigan fish (15 ppb) (consumption rate of 0-6 pounds/year [or 0-2.7 kg/year]). Halogenated contaminants (e.g., PCBs) have also been detected in adipose tissue, breast milk, and cord blood, associated with consumption of contaminated fish (ATSDR 1998). Other studies have also supported these findings. For example, Schwartz and others (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 and others 1983). Several studies of exposure to methylmercury through fish consumption are ongoing outside the Great Lakes basin. There have been no large-scale epidemiological studies of fish-eating population in the Lake Superior basin.

Although the levels of PCBs have declined in most species of Great Lakes fish, lipophilic pollutants, such as PCBs, have a tendency to bioaccumulate in the human body. Hovinga and others (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 and others 1996, Fitzgerald and others 1996, Lonky and others 1996, Schantz and others 1996). These communities may consume more fish than the general population or may have physiologic attributes such as physical and genetic susceptibilities that may cause them to be at greater risk. Higher body burdens of mean serum PCBs and DDE were found in an elderly cohort of Lake Michigan fisheaters (i.e., >50 years of age) who were compared to nonfisheaters (Schantz and others 1996). Fisheaters had mean serum PCB levels of 16 ppb while the nonfisheaters had mean levels of 6 ppb. For DDE, fisheaters had mean serum levels of 16 ppb and the nonfisheaters 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 Lake Michigan sport anglers study, with subjects between the ages of 18-34 years, also demonstrated gender differences with males tending to consume more fish than female subjects (Courval and others 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 (Dawson 2000), 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 or 1,762 of those interviewed, reported eating at least one meal of fish during the previous 12 months. Twenty-seven percent (465 individuals) 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*.

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.

In a study by Kearney and others done in 1992-93 (Kearney and others 1999), blood levels of PCBs in men and women between Great Lakes fish eaters and non-fish eaters were compared for Mississauga and Cornwall combined. For male fish eaters the median level was 5.5 µg/L, for male non-fish eaters it was 3.9 µg/L. For women fish eaters and non-fish eaters the median levels were 3.4 and 3.2 µg/L. These differences were statistically significant for men only. Relative to fish eaters and families on the North Shore of the St. Lawrence River (Dewailly and others) (geometric mean 35.2 µg/L) and Quebec Inuit (Sante Quebec 1994) (geometric mean 16.1 µg/L), these values are low. Nonetheless, there are uncertainties surrounding our knowledge of potential long term health effects of low level exposure to PCBs.

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 µg/L, respectively. Median levels for female Great Lakes fish eaters and non-eaters were 2.10 and 1.45 µg/L, respectively. Levels were generally at the lower end of the "normal acceptable range" (less than 20 µg/L) as defined by the Medical Services Branch of Health Canada and based on WHO guidelines. (Indian and Northern Affairs Canada 1997).

Hanrahan and others (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 and others (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.

5.2.3.2 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 which 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 and others 1984). These findings have also been observed in offspring of women exposed to PCBs occupationally in the manufacture of capacitors in New York (Taylor and others 1989).

Reproductive effects have also been reported. Courval and coworkers (1997, 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 and others 1995), nor an effect on time-to-pregnancy among women in this cohort (Buck and others 1997).

Neurobehavioral or neurodevelopmental effects have been documented for exposure to persistent toxic substances in newborns, infants, and children of mothers consuming Great Lakes fish. Early investigations of the Lake Michigan Maternal Infant Cohort revealed that 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 and others 1984). The fisheating 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 and others 1985) and at 4 years of age (Jacobson and others 1990b), and also growth deficits at 4 years associated with prenatal exposure to PCBs (Jacobson and others 1990a). A more recent investigation of Jacobson's Michigan Cohort has 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 µg/gram (ppm) in maternal milk, 4.7 ng/milliliter (ppb) in cord serum, or 9.7 ng/milliliter (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 human 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 to 24 and 25 to 48 hours). Lonky and others (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 and others (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. Initial testing for neurotoxic effects were not observed by Schantz and coworkers (1999) in an elderly adult population (i.e., ≥50 years) of Lake Michigan fisheaters 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 and others 1997, Tarvis and others 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). A summary of the health effect of methyl mercury can be found in a recent publication by Mahaffey (1999).

5.2.3.3 Future Research Needs

The potential long term effects of exposure to PBT chemicals have implications for future generations, and thus should remain a priority for public health investigation. Future research needs include:

1. *Need to continue to assess the role of PBT chemicals on neurobehavioural and neurodevelopmental effects*

2. *Need to improve the assessments of chemical mixtures*

Within our present state-of-knowledge, the human research demonstrating health effects from consumption of contaminated fish can be said to be relatively sound. Although these studies, in most cases, have made associations between a single contaminant detected in fish and the body burden or health effect, detections of multiple chemicals have been found in Great Lakes fish (Humphrey 1988; Dellinger and others 1996). Our present state-of-knowledge is vastly limited in identifying the subtle effect of multiple chemicals detected, even at low levels, in contaminated fish. For this reason, research is needed to clearly delineate whether a synergistic or additive effect occurs with multiple chemicals, and with a combination of chemicals having similar properties.

3. *Need to better assess the role that endocrine disruption may play in human heath effects, example reproductive health.*

Research has demonstrated that many of the contaminants found in fish from Lake Superior and other Great Lakes have been shown to adversely affect the endocrine system in fish and wildlife and laboratory animal studies. An environmental endocrine disruptor is ". . . an exogenous agent that interferes with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development, and/or behavior" (EPA 1997c). Some of the known endocrine disrupting chemicals include atrazine, chlordanes, DDT and metabolites, dieldrin, dioxins and furans, PCBs, and toxaphene (EPA 1997c). These are contaminants that have been detected in Lake Superior and other Great Lakes. Other substances, detected in the Great Lakes, are considered probable endocrine disruptors. These include cadmium, hexachlorobenzene, lead, mercury, and mirex. Although research continues on reproductive (Buck and others 1999; Courval and others 1999) and other effects that may be associated with exposure to endocrine disrupting chemicals, our knowledge about these substances in humans remains limited. Epidemiologic research needs to quantify the magnitude of exposures and effects of substances considered to be endocrine disruptors (EPA 1997c). Since endocrine disrupting chemicals, such as PCBs and DDT, have been detected simultaneously in fish, their effect as chemical mixtures also requires investigation.

4. *PCB Congeners*

Further human research is needed to identify the specific PCB congeners associated with adverse human health effects. The use of the capillary column gas chromatography, starting in the late 1980s and early 1990s, has enabled laboratories to identify the 209 PCB congeners (Communication with Virlyn Burse 2000). Stewart and coworkers (1999) found that the most heavily chlorinated PCB homologues (i.e., 7 or 8 chorines per PCB biphenyl ring) were significantly higher in the fetal cord blood of infants whose mothers had consumed Lake Ontario fish. These highly chlorinated and persistent PCB homologues were also detected in fish from Lake Ontario. Animal studies have supported this observation that highly chlorinated PCBs are responsible for adverse health effects. Congener-specific studies will help to identify those congeners that are most likely to adversely influence human health and require public health intervention.

5. Biologic Markers
Research has demonstrated that exposure on a regular basis to high levels of fish consumption can result in high body burdens of lipophilic contaminants such as PCBs and that the body burdens of these contaminants remains relatively constant in the body even after exposure cessation. For the goal of prevention, improved markers are needed to indicate biologic changes that predict health impairment or disease (NRC 1989) and the preclinical signs of disease (De Rosa and Johnson 1996). Currently funded research projects are examining body burdens of contaminants in serum, reproductive problems related to conception, and other health-related problems, that will be instrumental in identifying early warning signs requiring intervention. However, the biologic markers of exposure and effect often lack the precision to identify those who have an exposure, impairment, or disease, and those who do not. For this reason, additional research is needed to develop biologic markers that clearly identify the concentration of contaminants and the point in the human physiological process beyond which lasting adverse health effects will be observed.

5.2.3.4 Conclusion

For PBT chemicals, the current weight of evidence regarding human health effects is sufficient to support 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 PBT chemicals in the environment, both globally and regionally, are ultimately the most effective long-term solution to minimizing the health risks to the Lake Superior basin population. In addition, a shift in priorities is now needed to remediation, prevention, intervention, and collaborative activities, including the work of LaMPs.

5.3 HUMAN HEALTH INDICATORS TO MEASURE PROGRESS

Indicators and Targets for the Human Health Objectives were proposed in the LaMP's Ecosystem Principles and Objectives Discussion Paper. They include:

Table 5-4 Proposed Human Health Indicators for Lake Superior

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.

At the human health sessions of the Lake Superior LaMP Monitoring Workshop (October 25-27, 1999, Sault Ste. Marie, Ontario), it was agreed that radionuclides are not an issue for Lake Superior, and therefore the radionuclide indicator was dropped from the proposed list for indicator development. It was also agreed that sediments and soils needed to be added to the list in terms of considerations for indicator development, since they are indirect routes of exposure to PBT chemicals in terms of bioaccumulation through the food chain. In addition, it was agreed that the air pollution indicator needed to also make reference to atmospheric deposition so that PBT chemicals would also be considered.

Health Canada has developed a preliminary suite of health-related indicators as per the above list. These are published in the document *Health-Related Indicators for the Great Lakes basin Population: Numbers 1-20* (Health Canada 1998b), and they were also presented at the State of the Lakes Ecosystem Conference (SOLEC) 1998.

5.4 CONCLUSIONS AND IMPLEMENTATION PLAN

For persistent bioaccumulative toxic chemicals, the current weight of evidence regarding human health effects is sufficient to support 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 Superior basin population.

Although progress has been made in defining the health threat from Great Lakes pollutants (including Lake Superior pollutants), important issues remain requiring our diligent effort. To protect human health in the Lake Superior basin, actions must continue to be implemented on a number of levels. The Great Lakes Water Quality Agreement, under the Research and Development annex, calls for ". . . develop[ing] approaches to population-based studies to determine the long-term, low-level effects of toxic substances on human health" (IJC 1994). 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. In addition, a shift in priorities is now needed to remediation, 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 Lake Superior 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 individuals to make informed choices about their health.

Implementation: Programs targeted at Human Health and Environmental Contaminants in the Great Lakes basin Numerous Federal, State, Provincial and local government agencies, as well as environmental non-government organizations and communities are actively involved in the protection and promotion of human health as it relates to the environment. In particular, two Federal programs are in place to specifically address human health in the Great Lakes basin. In the U.S., the Agency for Toxic Substances and Diseases Registry addresses human health in the Great Lakes basin through its Great Lakes Human Health Effects Program. In Canada, Health Canada's Great Lakes Health Effects Program is addressing human health issues as they relate to the Great Lakes basin ecosystem. These programs are described in detail in Addendum 5-A.

Progress continues to be made to reduce the risk to health from exposure to environmental contaminants in the Great Lakes basin.

The following is a summary of the specific conclusions made in this chapter for drinking water, recreational water, fish/food consumption, and PBT chemicals.

5.4.1 Drinking Water Quality

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 assuring the safety of drinking water supplies. As the population grows, and as more people rely on the drinking water supply and participate in recreational activities such as swimming, 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.

5.4.2 Recreational Water Quality

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 1998b, Lake Erie LaMP 1999, Bartram and Rees 2000, U.S. EPA 1998a). Although it may not be feasible to eliminate exceedances of microbial levels completely in recreational use waters, it is expected that as sources continue to be remediated, exceedances and the threat to human health will continue to decline (Lake Erie LaMP 1999; U.S. EPA 1998a).

5.4.3 Fish Consumption

Diet contributes over 95 percent 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 persistent toxic substances from Great Lakes Sources, such as high consumers of sport fish. Because of the presence of PCBs, organochlorine insecticides, mercury, and other chemicals found in fish from the Lake Superior basin, fish advisories are issued that recommend restrictions on fish consumption, with tighter restrictions (in some cases to the point of complete elimination) of fish from the diet of pregnant women, women of childbearing age and children. In 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.

There are several areas that require future research and activity regarding fish consumption: 1)surveillance to evaluate how much fish people eat and carry out biomonitoring to determine actual tissue levels, particularly within sensitive populations, 2) incorporation of quantitative benefits of fish consumption into the risk assessment protocol for developing fish consumption advice 3) development of a meaningful indicator on time trends in how safe fish are to eat, 4) awareness of fish advisories needs to be increased, and 5) the effectiveness of fish advisories needs to be improved.

5.4.4 Persistent Bioaccumulative Toxic Chemicals

Since the 1970s, there have been steady declines in many persistent bioaccumulative toxic (PBT) chemicals in the Great Lakes Basin, leading to declines in levels in human tissues, for example, 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 Superior Basin. Therefore, the continued remediation and prevention strategies promoted by the Lake Superior LaMP Chemicals Document (need correct title and reference) should be prioritized along with public health advisories and other intervention activities for the protection of human health from current environmental exposures.

As stated earlier, demonstrating health effects in humans from chronic, low-level exposure to PBT chemicals typically encountered in the Great Lakes region poses a challenge for researchers. For example, human epidemiological studies are limited in their ability to separate health effects attributable to contaminant exposures from those related to other known health factors like smoking, alcohol intake and general health status. Despite these limits, neurodevelopmental and reproductive effects have been reported in some studies of human populations in the Great Lakes basin. In addition, developmental effects have been observed in wildlife and laboratory studies of PBT chemicals. Therefore, in defining the threat to human health from exposure to contaminants in the Lake Superior basin, a weight of evidence approach is often used, where the overall evidence from wildlife studies, experimental animal studies, and human studies is considered. These human and wildlife studies are sufficient to suggest that human health is at risk from exposure to PBT chemicals. The potential long-term effects have implications for future generations and thus should remain a priority for public health investigation.

5.4.5 Implementation Plan/Action Matrix

To protect human health in the Lake Superior basin, actions must continue to be implemented on a number of levels. Action items targeted at monitoring, research and protection of human health of Lake Superior basin residents are included in Table 5-5 below and the Lake Superior LaMP 2000 Action Matrix. 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.

For persistent bioaccumulative toxic chemicals, and in particular the PBT chemicals on Lake Superior's zero discharge list, the current weight of evidence regarding human health effects is sufficient to support 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, the continued reductions in the level of persistent pollutants in the environment are the most effective long-term solution to minimizing the health risks to people.

Table 5-5 Action/Implementation Plan Matrix

Description	Project Lead	Funding Status
Drinking Water		
Assess sources of drinking water. • For the U.S., EPA and all the Lake Superior 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. • 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 Ontario Drinking Water Surveillance Program	A A
Protect drinking water sources. This would include specific actions such as: wellhead protection plans and protection plans for water supply intakes on Lake Superior	U.S. states working with U.S. EPA and local communities; Health Canada/Ontario/ local communities	A
Raise awareness and improve the outreach 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; and 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 Superior 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	U.S. CDC, state and local health	

Table 5-5 Action/Implementation Plan Matrix

Description	Project Lead	Funding Status
response to disease outbreaks (such as in Milwaukee), improving information for epidemiological studies and for tracking trends over time (indicator).	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 Superior 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.)
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 Superior shoreline for their involvement. In parallel a Lake Superior indicator of recreational water quality that includes microbial data supplemented by beach postings should continue to be developed.	U.S. EPA, Health Canada with 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 Superior shoreline.	U.S. EPA BEACHs program, Health Canada, Ontario, state and local governments	A & B
Promote epidemiological research on water borne diseases in the Great Lakes and for the Lake Superior 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 an 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.	State health and natural resource agencies, U.S. EPA, Health Canada, Ontario	A & B

Table 5-5 Action/Implementation Plan Matrix

Description	Project Lead	Funding Status
Increase awareness, use and effectiveness of fish advisories in the Lake Superior populations targeting sensitive populations (minorities, women of child bearing age, immigrants, the elderly, etc.)	State and province government agencies, U.S. EPA, Health Canada, local governments	A & B
• U.S. EPA Study - Consortium for Improving the Effectiveness of Fish Consumption Advisories for Mercury Contaminated Sport Fish/Phase I - The states of Wisconsin and Maine received a grant from the U.S. EPA to assess mercury fish advisory awareness and fish consumption among women of childbearing age. As part of the project, focus groups were conducted in WI and ME to determine the channels by which women receive health information, obtain information about how they prefer to receive advisory information, and determine what they view as the central risk message that needs to be communicated. Childbearing age women from 12 states including WI and MN (in the Lake Superior basin) were contacted randomly by phone and surveyed about fish consumption habits, including commercial and sport-caught fish; awareness of the fish advisory; the modes by which they received the message; and whether they follow the advice. These women were also requested to send in a hair sample for mercury analysis. The results of this project will be available this year.	U.S. EPA/State of Wisconsin	A
• ATSDR grant to Consortium for the Health Assessment of Great Lakes Fish Consumption 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.	State of Wisconsin	A
GLIFWC Mercury in Walleye GIS Maps - Maps showing color coded inland lakes in MI, WI, and MN based on mercury content in walleye.		A

Table 5-5 Action/Implementation Plan Matrix

Description	Project Lead	Funding Status
Analysis of mercury in hair from MN Lake Superior basin residents	(Add on to UND/EERC project - use U.S. EPA LSBP human health committee project $?)	B
Screen fish from U.S. Lake Superior basin for suite of OCCs - as PCBs decline other OCCs will become an issue		B
Exposure and Health Effects Research		
Promote exposure, outcome and epidemiological research for PBT chemicals in the Great Lakes and specifically within the Lake Superior basin. This research should include the five needs for the future listed in Section 5.2.	NIEHS, U.S. EPA, Health Canada, Environment Canada, State, Provincial and Local Health departments	A & B
• Fish Consumption Study - Tracking tribal members' fish consumption. Several tribes are within the Lake Superior basin.	GLIFWC	A
• Contaminant testing of commercially-sold Lake Superior fish - Analyzed fillets from four commercially harvested species of fish for mercury, PCBs, and organochlorine pesticides. The study evaluates the effects of commercial processing methods (i.e., trimming and smoking) on contaminant concentrations.	GLIFWC	A
• Fish Consumption Survey: Minnesota and North Dakota - Residents of North Dakota and Minnesota, including some Lake Superior residents, will be surveyed to evaluate fish consumption patterns that can be used to estimate population exposure to mercury. This is a one year project. Survey design will begin in January 2000 and survey implementation in summer 2000.	DOE, utility industry, State of Minnesota, State of North Dakota sponsored project - University of North Dakota Energy & Environmental Research Center (EERC)	A
• EPA-CEM funded project - Grand Portage/Fond du Lac Fish Consumption Advice - Fish consumption advice will be developed for the Grand Portage Band of Chippewa and Fond du Lac Band of Lake Superior Chippewa. Due to a greater reliance on fish in their diets, the bands are potentially more exposed to bioaccumulative contaminants found in some fish. The project will include qualitative exposure assessment, fish sampling (including Lake Superior and tributaries), chemical analysis, advisory development and outreach (particularly to women of child-bearing age.)	U.S. EPA/MDH	A
• 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 "typical" 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

Table 5-5 Action/Implementation Plan Matrix

Description	Project Lead	Funding Status
examined. • ATSDR has awarded 10 research grants to study adverse human health effects from consumption of contaminated Great Lakes fish. These research activities and associated findings will be coupled with state and local public health activities designed to prevent adverse health effects in identified at-risk populations.	ATSDR	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 Superior basin	LaMP HH Committee, U.S. EPA, Health Canada, states and provinces working with the Great Lakes Commission and other LaMP partners	A
Assessment of social dimensions of health in the Lake Superior basin. Identify references available, and the need to address the social dimensions of health, further to the WHO definition of health.	LaMP HH Committee working with LaMP Partners. Health Canada, U.S. EPA	B
Literature review of wildlife consumption issues.		B
Need a better understanding of the chemical reactions and interactions in the transition zone between groundwater and surface water, to facilitate quantitative risk assessment of the potential effects of PBT contaminated sediments.		C

5.5 GLOSSARY AND ACRONYMS

Beneficial Uses - human health-related beneficial uses of Lake Superior include: fishable (We can all eat any fish); Drinkable (Treated drinking water is safe for human consumption; We can all drink the water); and Swimmable (All beaches are open and available for public swimming; We can all swim in the water).

Beneficial Use Impairments - Use impairments such as restrictions on fish and wildlife consumption and beach closings prevent populations in the Lake Superior basin from fully enjoying the beneficial uses of the lake.

Bioaccumulation - a generic term that refers both to biomagnification and bioconcentration

Bioconcentration - is the accumulation of a chemical in an organism from exposure to its environment

Biomagnification - a cumulative increase in the concentration of a persistent substance in successively higher trophic levels of the food chain

Chemical Contaminants - include naturally occurring chemicals and anthropogenic or synthetic chemicals

Critical Pollutants - for Lake Superior, nine critical pollutants have been targeted for zero discharge and virtual elimination.

Ecosystem - the interacting complex of living organisms and their non-living environment (U.S. EPA / Govt of Canada 1995)

Environmental Contaminants - substances foreign to a natural system or present at unnatural concentrations. They are unwanted substances that have entered the air, food, water or soil. They may be chemicals, living things, such as bacteria or viruses, or the products of radioactivity. Some contaminants are created by human (e.g. industrial) activities while others are the result of natural processes (Health Canada, The Health and Environment Handbook for Health Professionals 1998).

Exposure - any contact between a substance and an individual who has touched, breathed or swallowed it.

Exposure Pathways - the pathway a contaminant may take to reach humans or other living organisms; pathways include drinking water, recreational water and fish/food consumption (Health Canada 1998e).

Exposure routes - The three major routes that chemical and microbial pollutants enter the human body are by ingestion (water, food, soil), inhalation (airborne), and dermal contact (skin exposure).

Food Web - the process by which organisms in higher trophic levels gain energy by consuming organisms at lower trophic levels. Humans are at the highest level of many food webs (U.S. EPA / Government of Canada 1995, Health Canada 1998e)

Guideline - a recommended limit for a substance or an agent intended to protect human health or the environment that is not legally enforceable (Health Canada 1998e)

Great Lakes basin Ecosystem - the interacting components of air, land, water and living organisms, including humans, within the drainage basin of the St. Lawrence River at or upstream from the point at which this river becomes the international boundary between Canada and the United States (IJC 1987).

Human health - "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (World Health Organization 1984).

Microbial Contaminant - micro-organisms (e.g. bacteria, viruses, and protozoa such as cryptosporidium) that can cause disease

Persistent Bioaccumulative Toxic Chemicals - These chemicals do not break down easily, persist in the environment, and bioaccumulate in biota and animal and human tissues

Public Health Agencies - for Lake Superior, includes the State Departments of Health for Michigan, Minnesota, and Wisconsin; the Ontario Ministry of Health (Provincial); Health Canada (Federal); U.S. Agency for Toxic Substances and Diseases Registry (ATSDR, Federal); U.S. Centers for Disease Control (Federal); Public Health Units (municipalities in Ontario); Public Health Departments (State counties).

Standard - a legally enforceable limit for a substance or an agent intended to protect human health or the environment. Exceeding the standard could result in unacceptable harm. (Health Canada 1998e).

Toxicological Profiles - Toxicological Profiles have been prepared by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR), "for hazardous substances which are most commonly found at facilities on the CERCLA National Priorities List and which pose the most significant potential threat to human health, as determined by ATSDR and the Environmental Protection Agency" (U.S. Department of Health and Human Services 1992).

Toxic Substance - a substance which can cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological or reproductive malfunctions or physical deformities in any organism or its offspring, or which can become poisonous after concentration in the food chain or in combination with other substances (IJC 1987).

Weight of evidence approach - the weight of evidence approach considers all high-quality scientific data (i.e. the overall evidence) on adverse health effects from wildlife studies, experimental animal studies, and human studies in combination, toward hazard identification and in weighing the actual and potential adverse health effects of environmental contamination in human populations.

Acronyms

AFRI - Acute Febrile Respiratory Illness

BUIA - Beneficial Use Impairment Assessment

CCL - U.S. EPA Contaminated Candidates List

CSO - Combined Sewer Overflow

GLWQA - Great Lakes Water Quality Agreement

IJC - International Joint Commission

LaMPs - Lakewide Management Plans

MAC - Maximum Acceptable Concentration (used for Canadian guidelines)

MCL - Maximum Concentration Limit (used for U.S. standards and guidelines)

NPDWR - National Primary Drinking Water Regulations (U.S.)

PBT Chemicals - persistent, bioaccumulative toxic chemicals

PCBs - polychlorinated biphenyls - a class of persistent organic chemicals that bioaccumulate (U.S. EPA / Govt of Canada 1995).

SSO - Sanitary Sewer Overflow

SWPP - Source Water Protection Project

TDI - Total Daily Intake

TMDL - Total Maximum Daily Load

TOC - Total Organic Carbon

5.6 INTERNET INFORMATION RESOURCES AND FURTHER READING LAKE SUPERIOR HUMAN HEALTH ISSUES

5.6.1 General Internet Resources and Readings

United States
U.S. Environmental Protection @AGENCY Home Page
http://www.epa.gov/

U.S. EPA Great Lakes National Program Office
http://www.epa.gov/glnpo

U.S. EPA Region 5
http://www.epa.gov/

U.S. Center for Disease Control
http://www.cdc.gov/

U.S. Agency for Toxic Substances Disease Registry
http://www.atsdr.cdc.gov/

U.S. ATSDR Great Lakes Health Effects Program
http://www.atsdr.cdc.goc/grlakes.html

States
Michigan Department of Community Health
http://www.mdch.state.mi.us/

Minnesota Department of Health
http://www.health.state.mn.us/

Wisconsin Department of Health
http://www.dhfs.state.wi.us/

Canada
Health Canada General Home Page
http://www.hc-sc.gc.ca/

Health Canada, Environmental Health Program Home Page
http://www.hc-sc.gc.ca/ehp/ehd/

Province
Ontario Ministry of Health
http://www.gov.on.ca/health/index.html

Readings

ATSDR (Agency for Toxic Substances and Disease Registry). 1993. Aldrin/Dieldrin Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1995. Chlordane Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1999. Chlorinated Dibenzo-p-Dioxins Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1995. DDT, DDE, and DDD Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Hexachlorobenzene Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1999. Mercury Fact Sheet. Atlanta, Georgia U.S. Department of Health and Human Services.

ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Polychlorinated Biphenyls Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

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ATSDR (Agency for Toxic Substances and Disease Registry). 1997. Toxaphene Fact Sheet. Atlanta, Georgia: U.S. Department of Health and Human Services.

Health Canada. 1998. Jackfish Bay Area of Concern: Health Data and Statistics for the Population of the Township of Terrace Bay. (1986-1992)

Health Canada. 1998. Nipigon Bay Area of Concern: Health Data and Statistics for the Population of the Region. (1986-1992)

Health Canada. 1998. Peninsula Harbour Area of Concern: Health Data and Statistics for the Population of Marathon. (1986-1992)

Health Canada. 1998. Thunder Bay Area of Concern: Health Data and Statistics for the Population of the Region. (1986-1992)

Health Canada. 1997. State of Knowledge Report on Environmental Contaminants and Human Health in the Great Lakes basin.

International Joint Commission. Revised Great Lakes Water Quality Agreement of 1978 as Amended by Protocol Signed November 18, 1987. Reprint February, 1994.

U.S. EPA and Government of Canada, 1995. The Great Lakes: An Environmental Atlas and Resource Book.

Johnson, B.L., H.E. Hicks, D.E. Jones, W. Cibulas, A. Wargo and C. T. De Rosa. 1998. Public Health Implications on Persistent Toxic Substances in the Great Lakes and St. Lawrence basins. Journal of Great Lakes Research. 24(2): 698-722.

5.6.2 Internet Resources and Further Readings for Air:

Canada
Air Pollution Health Effects Research Program in its Environmental Health Directorate
http://www.hc-sc.gc.ca/ehp/ehd/bch/air_quality.htm

Health Canada/Santé Canada. *Outdoor Air and Your Health: A summary of Research Related to the Health Effects of Outdoor Air Pollution in the Great Lakes basin. / L'atmosphère et votre santé: Résumé de la recherche relative aux effets sur la santé de la pollution atmosphérique dans le bassin des Grands Lacs*. (Bilingual/bilingue). Great Lakes Health Effects Program/Le programme <Les Grands Lacs: Impact sur la santé>, March/Mars 1996.

United States
EPA Office of Air and Radiation
http://www.epa.gov/oar/oarhome.html

U.S. EPA Health Effects Notebook for Hazardous Air Pollutants
http://www.epa.gov/ttn/uatw/hapindex.html

OSHA Indoor Air page:
http://www.osha-slc.gov/SLTC/indoorairquality/index.html

5.6.3 Internet Resources and Further Readings for Drinking Water:

Canada
Health Canada, 1999. Drinking Water Quality home page, at web site
http://www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm

Ontario Ministry of Environment, Drinking Water Surveillance Program. This web site provides executive summaries describing the performance of municipal water treatment facilities monitored under DWSP, for the years 1996-97.
http://www.ene.gov.on.ca/envision/dwsp/index96_97.htm

United States
U.S. EPA Office of Ground Water and Drinking Water Home Page
http://www.epa.gov/safewater/about.html
http://www.epa.gov/OGWDW/wot/appa.html
http://www.epa.gov/ogwdwooo/hfacts.html

U.S. EPA, How Safe is my Drinking Water? Office of Ground Water and Drinking Water
http://www.epa.gov/OGWDW/wot/howsafe.html

U.S. EPA, Current Drinking Water Standards - National Primary and Secondary Drinking Water Regulations. Office of Groundwater and Drinking Water web site at
http://www.epa.gov/OGWDW/wot/appa.html

U.S. EPA, Consumer Confidence Reports. Fact Sheet. At web site
http://www.epa.gov/safewater/ccr/ccrfact.html

USFDA Food borne Pathogenic Microorganisms and Natural Toxins Handbook Web Page
http://vm.cfsan.fda.gov/~mow/chap24.html

U.S. Center for Disease Control. Cryptosporidiosis Fact Sheet.
http://www.cdc.gov/ncidod/diseases/crypto/cryptos.htm

Readings
Wisconsin Department of Natural Resources, 1998. ACryptosporidium: " Risk to our Drinking Water." Fact Sheet. Available on WDNR web site at
http://www.dnr.state.wi.us/org/water/dwg/Crypto.htm#what steps Revised June 1, 1998.

Health Canada, 1993. The Undiluted Truth about Drinking Water.

Health Canada, 1995. Great Lakes Water and Your Health: A summary of AGreat Lakes basin Cancer Risk Assessment: "Case-control Study of Cancers of the Bladder, Colon and Rectum"

Health Canada, 1998b. Health Canada Drinking Water Guidelines. It's Your Health Fact Sheet Series, May 27, 1997.

5.6.4 Internet Resources and Further Readings for Recreational Water

Canada
Health Canada, 1999. It's Your Health: Recreational Water Quality.

United States
U.S. EPA, Office of Water, EPA's BEACH Watch Program, 1999 Update

http://www.epa.gov/OST/beaches/update.html

U.S. EPA's BEACH Watch Program Homepage
http://www.epa.gov/OST/beaches/

U.S. EPA Office of Water, BEACH Watch Program Homepage.
http://www.epa.gov/OST/beaches/

U.S. EPA Office of Water, BEACH Watch Program. Local Beach Health Information.
http://www.epa.gov/OST/beaches/local/

Natural Resources Defense Council (NRDC). Testing the Waters - 1999 - A Guide to Water Quality at Vacation Beaches
http://www.igc.org/nrdc/nrdcpro/ttw/titinx.html

Health Canada. "It's Your Health" Series: Recreational Water Quality
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/recwater.htm

5.6.5 Internet Resources and Further Readings for Fish/Food Consumption

Canada (Ontario)
Ontario Ministry of the Environment. Guide To Eating Ontario Sport Fish 1999 - 2000
http://www.ene.gov.on.ca/envision/guide/index.htm

United States
U.S. EPA Fish Consumption Advisory Information
http://www.epa.gov/OST/fish/

States
Michigan Department of Community Health. Michigan Fish Advisory
http://www.mdch.state.mi.us/pha/fish/index.htm

Minnesota Department of Natural Resources. Minnesota Fish Advisory
http://www.dnr.state.mn.us/lakefind/fca/index.html

Wisconsin Department of Natural Resources. Wisconsin Fish Advisory
http://www.dnr.state.wi.us/org/water/fhp/fish/advisories/

5.6.6 Internet Resources and Further Readings for Health Effects Information

ATSDR's Toxicological Profiles
http://www.atsdr.cdc.gov/toxpro2.html

ATSDR HAZDAT Database: Hazardous Materials and their Human Health Effects
http://atsdr1.atsdr.cdc.gov:8080/hazdat.html

ATSDR, Public Health Implications of Exposure to Polychlorinated Biphenyls (PCBs)
http://www.atsdr.cdc.gov/DT/pcb007.html

U.S. EPA Mercury Study Report to Congress
http://www.epa.gov/ttn/oarpg/t3/reports/volume5.pdf

5.6.7 Lake Superior AOCs

Saint Louis River
http://www.epa.gov/glnpo/aoc/stlouis.html

Torch Lake
http://www.epa.gov/glnpo/aoc/trchlke.html

Deer Lake
http://www.epa.gov/glnpo/aoc/drlake.html

Saint Marys River
http://www.cciw.ca/glimr/raps/connecting/st-marys/intro.html

Peninsula Harbor
http://www.cciw.ca/glimr/raps/superior/peninsula/intro.html

Jackfish Bay
http://www.cciw.ca/glimr/raps/superior/jackfish-bay/intro.html

Nipigon Bay
http://www.cciw.ca/glimr/raps/superior/nipigon-bay/intro.html

Thunder Bay
http://www.cciw.ca/glimr/raps/superior/thunder-bay/intro.html

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ADDENDUM 5-A
ATSDR AND HEALTH CANADA PROGRAM SUMMARIES

U.S. Agency for Toxic Substances and Disease Registry and Health Canada summaries of programs for the Great Lakes.

ATSDR:
The ATSDR's Great Lakes Human Health Effects Research Program (GLHHRP) serves as a model by which the requirements of the human health component of the Great Lakes Water Quality Agreement are being met. The goals of the GLHHRP are to 1) identify the populations at risk who may be exposed to chemical contaminants from the Great Lakes, and 2) prevent the potential adverse human health effects that research has demonstrated is associated with exposure. These goals represent the program's public health focus intended to protect the health of populations consuming contaminated Great Lakes fish. ATSDR has established an applied research strategy to achieve these goals based upon the traditional model of disease prevention (De Rosa and Johnson 1996, Johnson and others. 1998). These strategies are key requirements of the human health component of the Great Lakes Water Quality Agreement.

The GLWQA calls for the LaMPs "... to include a definition [description] of the threat to human health . . . posed by Critical Pollutants, singly or in synergistic or additive combinations . . . ." (IJC 1994**).** The GLWQA also calls for the establishment of a surveillance and monitoring system, one of whose purposes it to identify emerging problems. For ATSDR, identification has involved identifying vulnerable populations and cohorts of populations who consume contaminated fish and have a potential for developing adverse human health effects (Anderson and others 1996; Courval and others 1996, 1999; Daly and others 1996; Fitzgerald and others 1996, 1999; Schantz and others 1996; Stewart and others 1999; Vena and others 1996; Waller and others 1996). The ATSDR cohort populations are part of a surveillance and monitoring system to identify emerging problems of long-term health effects associated with consumption of contaminants in fish.

Evaluation is another ATSDR strategy element used to determine causal linkages or conclusions regarding biologic plausibility. Early reports from the ATSDR's GLHHRP have demonstrated exposure associations between consumption of contaminants in Great Lakes fish and body burdens particularly for those with high fish consumption. The program has entered into a second evaluation phase in which associations are being established between body burdens of contaminants (e.g., in serum) and health effects observed in humans and animals.

As with the GLWQA, implementation is an integral part of ATSDR's strategy. Having helped to establish the pathway of exposure for at-risk populations, ATSDR's prevention strategy involves risk communication and health education to minimize the public's exposure to contaminants in fish (Tilden and others 1997). Health advisories for fish consumption are important means of communicating to the public the potential toxic effect from contaminants in Great Lakes fish. An ATSDR-funded research group has helped to develop uniform health advisory guidelines for fish consumption that is being utilized by the Great Lakes states. In addition to the funded research, ATSDR is presently preparing a report assessing health advisories for fish consumption within the Great Lakes states. This report will include an examination of some of the outreach approaches (e.g., pamphlets, posters, Internet) used by the Great Lakes states to disseminate health advisory information. As a further component of the prevention strategy, ATSDR has an ongoing program dealing with the effect of mixtures of chemicals found in the Great Lakes and other sites to determine synergistic or additive effects of these chemical mixtures (Hansen and others 1998). Within the next year, a toxicological profile will be published by ATSDR describing the state-of-the-science for chemical mixtures found in the Great Lakes and other hazardous waste sites.

As part of the impact assessment, ATSDR has established a process by which the GLHHRP projects are reviewed. Results of these research projects are customarily published to expand the public's awareness of potential adverse human health effects from consuming contaminated fish. ATSDR has also been participating in the Lakes Erie, Michigan, and Superior LaMP work groups, and has utilized this opportunity to 1) develop a human health section document that can be utilized as a prototype for all LaMPs, 2) inform the governmental and non-governmental agencies and the public about recent findings from the ATSDR funded research, and 3) develop an awareness about the current health-related issues in the Great Lakes basin that can assist in the direction of the GLHHRP.

This strategy and its component elements have represented major strides in helping to fulfill the requirements of the Great Lakes Water Quality Agreement by delineating the potential human health threat from contaminants in Great Lakes fish and by implementing actions that will protect human health. Having achieved these major steps, ATSDR is now making an effort to advance the science in relatively pristine areas such as mixtures effects from multiple chemicals found in the Great Lakes and other sites (Hansen and others. 1998), and the development of biomarkers of exposure. This step-by-step process will also be instrumental in building a data base of knowledge that can be utilized in dealing with other health- and environmental-related issues both nationally and internationally.

Health Canada's Great Lakes Health Effects Program.

Canadian federal government action to clean up and protect the Great Lakes ecosystem and fulfill Canada's international obligations under the Canada/USA *Great Lakes Water Quality Agreement* was formalized in 1989 with the launch of the Great Lakes Action Plan, a five year partnership between five departments, including Health Canada. The program was renewed in 1994 as the Great Lakes 2000 initiative, a six year partnership among seven federal departments. Federal actions to clean-up and protect the Great Lakes ecosystem are continuing under multi-departmental Great Lakes 20/20 Action Plan, toward fulfilling Canada's international obligations under the Canada-U.S. *Great Lakes Water Quality Agreement*.

The Great Lakes Health Effects Program (GLHEP) is Health Canada's contribution to the federal Great Lakes Program and the Canada-U.S. *Great Lakes Water Quality Agreement*. GLHEP's Mission is to protect the health of the Great Lakes basin population from the effects of exposure to environmental contaminants. Three major goals shape the Great Lakes Health Effects Program: To determine the nature, magnitude, and extent of effects on human health associated with exposure to contaminants (chemical, biological, radiological) from all sources of pollution in the Great Lakes basin.

- To manage the risks to human health related to pollution in the Great Lakes basin.
- To communicate and consult among agencies and the public and support informed decision making on health and environment issues.

Since 1989, GLHEP has conducted research on human exposure to environmental contaminants and on their effects on health. In addition, GLHEP has consulted with the public, professionals and industries throughout the Great Lakes basin, and has supported communities in addressing health and environment issues, including remedial actions within the 17 Canadian Areas of Concern (AOCs). GLHEP is a resource of information and expertise to a wide variety of audiences toward promoting and protecting human health from contaminants in the Great Lakes Basin.

GLHEP has worked in partnership with a range of partners to produce:

- research papers and technical documents detailing the latest state of knowledge on human health and the Great Lakes basin ecosystem;
- resource tools and materials for intermediaries such as educators and public health professionals, to assist them in providing health and environment advice and information to the public, and
- plain language audio/visual and written materials for the general public, to assist them in making informed choices about their health as it relates to the environment.

The GLHEP addresses human health from an ecological perspective, and has been involved with the Lake Superior, Lake Erie and Lake Ontario Lakewide Management Plans from their inception in the early 1990's. For the Lake Superior LaMP, GLHEP has participated on the LaMP Task Force, Work Group, and the Ecosystem Objectives Subcommittee, providing health expertise and advice, and ensuring that human health is considered at every step of the LaMP process. Further to this, GLHEP played an integral role in the recent development of the Human Health Subcommittee for the Lake Superior LaMP, providing co-chair function and working with a diverse range of health experts on this group.

For further information about Health Canada’s Great Lakes Health Effects Program, or to request our publications, contact:

Great Lakes Health Effects Program
Health Canada