HEALTH CONSULTATION

EVALUATION OF SAGINAW RIVER DIOXIN
EXPOSURES AND HEALTH RISKS

SAGINAW RIVER
CITY OF SAGINAW, SAGINAW COUNTY, MICHIGAN

Prepared by:

Michigan Department of Community Health
Under A Cooperative Agreement with the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviations and Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
CDC	United States Centers for Disease Control and Prevention
CDD	Chlorinated dibenzo-dioxins
CDF	Chlorinated dibenzo-furans
DLC	Dioxin-like compound
EPA	U.S. Environmental Protection Agency
g/d	Grams per day
I-TEQ	International 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalency, which are based on 1989 toxic equivalency factors
kg	Kilograms
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
mls/mth	Meals per month
NTP	National Toxicology Program
PCBs	Polychlorinated biphenyls
pg	picograms
ppt	parts per trillion
ppt-$TEQ_{d,f,\ WHO\ 2005}$	parts per trillion 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalencies summed to include 2,3,7,8 dioxin congeners and 2,3,7,8 furan congeners that are calculated using WHO 2005 mammalian toxic equivalency factors.
ppt-$TEQ_{d,f,p\ WHO\ 2005}$	parts per trillion 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalencies summed to include 2,3,7,8 dioxin congeners; 2,3,7,8 furan congeners; and dioxin-like polychlorinated biphenyls that are calculated using WHO 2005 mammalian toxic equivalency factors.
ppt-$TEQ_{d,f\ WHO\ 1998}$	parts per trillion 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalencies summed to include 2,3,7,8 dioxin congeners; 2,3,7,8 furan congeners; that are calculated using WHO 1998 mammalian toxic equivalency factors.
ppt-$TEQ_{d,f,p\ WHO\ 1998}$	parts per trillion 2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalencies summed to include 2,3,7,8 dioxin congeners; 2,3,7,8 furan congeners; and dioxin-like polychlorinated biphenyls that are calculated using WHO 1998 mammalian toxic equivalency factors.
SBW	Saginaw Bay Watershed
TCDD	Tetrachlorodibenzo-*p*-dioxin
TEF	Toxic equivalency factor
TEQ	2,3,7,8-tetrachlorodibenzo-*p*-dioxin toxic equivalency
Saginaw Waters	Tittabawassee River/ Saginaw River/ Shiawassee River/Saginaw Bay
US FDA	United States Food and Drug Administration
WHO	World Health Organization

Summary

The Michigan Department of Environmental Quality (MDEQ) has shown that Saginaw River sediments, riverbank soils, and fish contain elevated amounts of dioxin-like chemicals (DLCs). The Michigan Department of Community Health (MDCH) has documented fish consumption patterns of people eating fish from the Saginaw River and surrounding waters. Based on reported consumption of fish from the Saginaw River and associated tributaries, MDCH finds that many of the current consumption patterns of Saginaw River fish are a *Public Health Hazard*.

Purpose and Health Issues

Purpose

This health consultation evaluates the risk to human health from exposure to dioxin-like chemicals (DLC) found in Saginaw River fish, flood plain soils, and sediments.

Petitioned Health Consultation

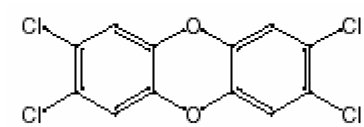
This health consultation is in response to a petition filed in April 2006 with the Agency for Toxic Substances and Disease Registry (ATSDR) (Appendix 1). The petition was accepted by ATSDR as an extension to a similar request regarding the Tittabawassee River in 2001. Public health consultations regarding the Tittabawassee River can be found at www.michigan/mdch-toxics under the link *Health Assessments and Consultations*.

Basis for Public Health Concern

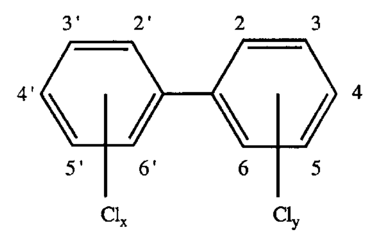
For the purpose of this health consultation, dioxin-like chemicals (DLCs) included seven chlorinated dioxins, 10 chlorinated furans, and 12 polychlorinated biphenyls (PCBs) that can cause harm in a similar manner. These DLCs are found mixed together in the Saginaw River sediment (soil underwater), flood plain soil, and animals (e.g. fish). Given the similar manner of toxicity and that these chemicals are found as mixtures in the Saginaw River, this health consultation evaluates the combined risk of these chemicals.

DLCs vary in their levels of toxicity. The most toxic DLC is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) (Figure 1). MDCH expects the remaining DLCs to be either less toxic or equally toxic compared to 2,3,7,8-TCDD. In order to evaluate mixtures of DLCs found in and along the Saginaw River, MDCH uses toxic equivalency factors (TEFs) (Van den Berg et al. 2006). TEFs are numbers between 0.00003 and 1.0

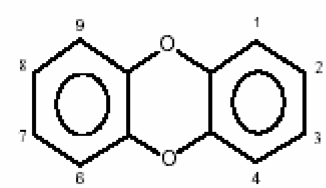
that are used to represent the relative toxicity of these other DLCs compared to that of 2,3,7,8-TCDD. If a DLC has a



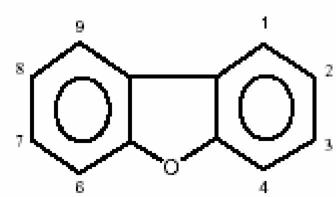
2,3,7,8-Tetrachlorodibenzo-p-dioxin



Polychlorinated Biphenyls.



Chlorinated Dioxins



Chlorinated Furans

Figure 1. Generalized structures of dioxins, furans and polychlorinated biphenyls and the structure of 2,3,7,8-TCDD.

TEF of 1, then the chemical is expected to be as toxic as 2,3,7,8-TCDD. MDCH multiplies measured levels of DLCs in environmental samples (e.g. soil or fish tissue) by the chemical specific TEF to calculate a 2,3,7,8-TCDD toxic equivalent (TEQ) concentration. MDCH adds all the resulting TEQs from a sample to estimate the total TEQ concentration.

The two public health questions addressed in this document are:

1. Do people engaging in activities on the Saginaw River come into contact with these DLCs?

2. For people that come into contact with the Saginaw River DLCs, do any activities result in chemical exposures that increase human health risks to unsafe levels?

Background

The Saginaw River, located on the Lower Peninsula in east central Michigan, is 22 miles in length with a channel width that can exceed 650 feet and a depth that can exceed 14 feet (Figure 2). The Saginaw River empties into Lake Huron's Saginaw Bay. Tributaries of the Saginaw River include the Cass, Flint, Shiawassee, and Tittabawassee Rivers. The Saginaw River and its tributaries flow through several large cities including Flint, Midland, Saginaw, and Bay City. Demographically, these cities vary in their racial and ethnic characteristics (Table 1). The cities of Saginaw and Flint have majority non-white or Hispanic populations. Historically, DLCs from industrial sources located along these tributary rivers were released and ultimately entered the Saginaw River.

Table 1 Demographic information for the four major cities and their respective counties through which the Saginaw River or its major tributaries flow.

Category	**State of Michigan**	**County**			
		Bay	**Genesee**	**Midland**	**Saginaw**
Total Population	9,938,444	110,157	436,141	83,792	210,039
African-American	14.2%	1.4%	20%	1.2%	19.3%
Asian	1.8%	0.5%	0.9%	1.8%	1.0%
Hispanic/Latino	3.3%	4.1%	2.4%	1.7%	7.1%
Native American	0.6%	0.5%	0.5%	0.4%	0.5%
White Non-Hispanic	77.9%	92.6%	74.5%	94.2%	71.4%
		City of			
		Bay City	**Flint**	**Midland**	**Saginaw**
Total Population		36,817	124,943	41,685	61,799
African-American		2.7%	53.3%	1.8%	43.3%
Asian		0.5%	0.4%	2.7%	0.3%
Hispanic/Latino		6.7%	3.0%	1.9%	11.7%
Native American		0.4%	0.6%	0.3%	0.5%
White		91.2%	41.4%	93.4%	47.0%

Michigan Department of Environmental Quality (MDEQ) has found Saginaw River sediments and river animals (e.g. fish) to have elevated concentrations of DLCs. In 2006, the MDEQ reported DLCs in Saginaw River sediments and flood plain soils (MDEQ 2006). The MDEQ Fish Contaminant Monitoring Program reported DLC contamination in fish from the Tittabawassee River, Saginaw River, and Saginaw Bay (MDEQ 2005). MDCH in cooperation with ATSDR has previously published health consultations on human exposures to dioxin and furan contamination found in the Tittabawassee River and on its flood plain (ATSDR 2005, MDCH 2005) and PCB contamination of the Saginaw River (MDCH 1996).

Based on elevated levels of DLC and total PCB contamination found in fillets of Tittabawassee River, Saginaw River, and Saginaw Bay fish, Michigan has issued public health advisories on all species of fish beginning in the late 1970s. These public health advisories suggest that people either limit or not eat certain species of fish. On average, the most contaminated fish species from these waters are carp, followed by white bass, catfish, and lake trout. The walleye and yellow perch are the least contaminated with DLCs. Smallmouth bass and largemouth bass are more contaminated than walleye and yellow perch. Several species have not been tested for DLCs, such as crappie, northern pike, and bluegill. Given that these species reside more permanently in the Saginaw River and have some similar feeding patterns to walleye or yellow perch, these species will likely be similar to or more contaminated than walleye and yellow perch.

In June 2007, MDCH released a report on the fish consumption patterns of people who were interviewed while fishing the Tittabawassee River, Saginaw River, Shiawassee River, or Saginaw Bay (Saginaw Waters) (MDCH 2007). The objective of the study was to characterize the fish consumption patterns of people who harvest and eat fish from waters in the Saginaw Bay Watershed (SBW). The study focused on SBW waters that were frequently fished by large numbers of people. The study design assumed that most fishers live locally and fish these waters on a regular basis.

The MDCH SBW fish consumption study interviewed 1088 people fishing the Saginaw Waters. A total of 907 fishers reported eating fish (i.e., fish consumers) from waters in Michigan. MDCH asked fish consumers follow-up questions regarding their awareness and understanding of the Michigan fish consumption advisory; fish consumption from the river being fished at the time of the interview; fish consumption from other sources not including the river being fished at the time of the interview; and demographic information.

Fish consumers ranged in age from 17 to 79 years and were predominantly male (843 males, 60 females) and white (786 white, 95 African-Americans, 15 other individuals of various non-white racial and ethic backgrounds). Greater than 97% of the fish consumers had their primary residence in Michigan, with 82% of fish consumers being from Saginaw County (37%), Bay County (25%), or an immediately adjacent county (20%). This finding confirms the study design assumption that the majority of people consuming locally harvested fish are local residents. When fish consumers were asked which waters they regularly fish in the SBW, the most frequently reported waters were Saginaw Bay

(373 responses), Saginaw River (238 responses), and the Tittabawassee River (124 responses). Of fish consumers, 79–85% responded that their fish consumption patterns were the same as the other people living in their home, including children.

Of the 907 fish consumers in the study, 634 stated that they eat the fish they catch from the river that they were fishing at the time of the interview. Of these, 47% were fishing the Saginaw River (Saginaw River 297, Saginaw Bay 163, Tittabawassee River 128, and Shiawassee River 46). Using these responses, MDCH calculated the distribution of fish meals per month eaten by respondents.

MDCH further reported differences between males and females, and between races regarding awareness of the existence of the Michigan fish consumption advisory. Thirty-seven percent of the female fish consumers fishing and eating fish from the Saginaw Waters were not aware of the existence of the advisory compared to 15% of male fish consumers. Female fish consumers were more likely to prefer eating bass (21%) and catfish (15%). Male fish consumers preferred eating walleye (49%) and yellow perch (24%) with a smaller percentage consuming bass (6%) and catfish (6%).

Twelve percent of individuals, identifying themselves as *white*, were not aware of the existence of the Michigan fish consumption advisory compared to 48% of individuals self-identifying as a race other than white (primarily Africa-American). Thus four times as many *minority* fish consumers fishing and eating fish from the Saginaw Waters were not aware that Michigan advises people to either restrict consumption or not eat the fish from these rivers.

The Michigan fish consumption advisory states that nobody should eat carp or catfish from the Tittabawassee or Saginaw Rivers. Of the *minority* consumers eating fish from the Saginaw Waters, 62% were eating catfish and 7% were eating carp compared to *white* consumers (7% catfish and 1% carp). In addition, more *minority* consumers stated they consume smallmouth bass (22%), largemouth bass (10%), white bass (16%), and crappie (19%), compared to *white* consumers (smallmouth bass 8%, largemouth bass 3%, white bass 3%, and crappie 3%).

Many people are fishing and eating fish from the Saginaw River. These fishers may also unintentionally swallow small amounts of sediment, soil, or dust that contain DLCs. Additionally, these fishers are taking their Saginaw River fish home to feed to their families. Based on the MDCH study, minority fish consumers and female fish consumers are more likely eating the higher DLC contaminated fish species from the Saginaw River. This ATSDR Health Consultation describes the amount of DLC exposures and the associated risk from engaging in Saginaw River activities.

Discussion

Environmental Contamination

Saginaw River Flood Plain Soil Concentrations

The MDEQ has reported that Saginaw River sediments are contaminated with elevated levels of DLCs (average = 750 parts per trillion-2,3,7,8 TCDD toxic equivalents (ppt-

TEQ), range = 0.01 to 16,000 ppt-TEQ) (MDEQ 2006). River sediments can deposit in frequently flooded areas along the Saginaw River; however the Saginaw River does not have an extensive flood plain. In an initial flood plain soil sampling (41 flood plain soil samples), the MDEQ reported the top 1-inch of soil to have levels of DLCs ranging from 0.7 to 144 ppt-$TEQ_{d,f,p\ WHO\ 2005}$ (Appendix 2).

Fish Fillet Concentrations for the Saginaw River and Connected Waters
The MDEQ Fish Contaminant Monitoring Program tested one species of fish from the Saginaw River (i.e., carp) and six species from the Saginaw Bay (catfish, carp, lake trout, white bass, yellow perch, and walleye) (Table 2) (Appendix 3). Michigan Department of Natural Resources (MDNR) fisheries biologists explain that walleye, for spawning purposes, swim from Saginaw Bay up the Saginaw and Tittabawassee Rivers. Other species, such as smallmouth bass, carp, and catfish reside more locally within a single water body. For this health consultation, MDCH used the walleye data from the Saginaw Bay and Tittabawassee River to estimate the average walleye fillet DLC concentrations. MDCH used Saginaw Bay catfish, carp, white bass, lake trout and yellow perch to represent DLC concentrations in Saginaw River fish fillets. Using Saginaw Bay fish tissue concentrations may underestimate DLC concentrations in similar species from the Saginaw River. In 2004, MDEQ measured DLCs in fillets from 10 Saginaw Bay carp (average= 200 ppt-TEQ, range 7 – 1,500 ppt-TEQ) and 10 Saginaw River carp (average= 590 ppt-TEQ, 2.6 – 3000 ppt-TEQ) suggesting that resident Saginaw River fish may be more contaminated than resident Saginaw Bay fish.

During 2007 additional fish from the Saginaw River were being collected and tested for DLC. At the time of release of this health consultation, only a portion of this data had been reported. That available data was currently undergoing review to determine its quality. Comparing the new available data by species to the previous data, the new data were generally similar to the previous data.

DLC fish tissue concentration may have been greater in the past. MDEQ (2006) reports that whole lake trout from Thunder Bay, Lake Huron are declining in DLCs by 4% per year and Saginaw Bay carp are declining in DLC by 5% per year.

Table 2 Saginaw Bay (SB), Saginaw River (SR), and Tittabawassee River (TR) DLC fish tissue concentrations representing Saginaw River DLC fish tissue concentrations.

Species	**Water Body**	**Years**	**Number of Samples**	**Length Range cm**	**Weight Range grams**	**Average DLC Fillet Concentrations ppt-TEQ**
Catfish	SB	‘99, ‘04	20	37-64	510-2,720	16
Carp	SB & SR	‘91, ‘92, ‘04	40	37-74	730-6,400	420
Lake Trout	SB	‘93	10	51-72	1,440-3,880	13
White Bass	SB	‘04	10	22-36	170-630	17
Yellow Perch	SB	‘04	10	20-29	100-315	0.71
Walleye	SB, TR	’92, ’94, ’00, ’03, ‘04	42	37-59	410-2,120	2.6

Background DLC Concentrations

<u>National Food Supply</u>
The United States Food and Drug Administration (US FDA) tests the national food supply for dioxins and furans (**http://www.cfsan.fda.gov/~lrd/dioxee.html**). MDCH summarized the most recent results (Table 3) by food group. The US FDA uses the WHO 1998 TEF estimates (Van den Berg et al. 1998) to calculate the amount of DLCs in the food. A more recent method by the WHO (Van den Berg et al. 2005) is now available. Given that the US FDA website does not provide the raw data, which are necessary to apply the WHO 2005 method, the data provided in Table 2 may overestimate the dioxin and furan concentrations on average by approximately 25% (Wittsiepe et al. 2007). However, the US FDA did not measure for the PCB DLCs, which would underestimate the DLC food concentrations. Schecter et al. (1997, 2001) reported that, on average, PCB DLCs contribute approximately 28-33% of the total DLC content in US food. Given the very low concentrations of DLC in the national food supply and the above considerations, MDCH used the US FDA 2004 reported results without any adjustments as background concentrations found in the national food supply.

Table 3 Average DLC TEQ concentrations by food group for the 2004 US FDA dioxin and furan data.

Food Group	**Dioxin/Furan TEQ Concentrations ppt-TEQ***
Beef	0.195
Dairy	0.083
Eggs	0.016
Fish	0.062
Milk	0.004
Pork	0.007
Poultry	0.003
Vegetable Oil	0.008

* TEQ calculated using Van den Berg et al. 1998.

<u>Michigan's Soil Concentrations</u>
MDEQ has reported background dioxin and furan soil concentration in Michigan to average 6 ppt-TEQ. This concentration was calculated before the most recent WHO methods (Van den Berg et al. 2005) were available and does not include PCB DLC concentrations. However, given the low concentrations of DLCs in average Michigan soils and the insignificant contribution to risk or intake that soil concentrations less than 90 ppt-TEQ have, MDCH used the concentration of 6 ppt-TEQ as the background soil concentration in Michigan.

<u>**Exposure Pathways Analysis**</u>

Saginaw River DLCs can cause harm to human health only if those chemicals move from the environment and accumulate in a person's body. The movement of DLCs from the environment into a person's body is called the exposure pathway.

An exposure pathway contains five parts: (1) a source of contamination, (2) contaminant transport through an environmental material (i.e., soil, air, water, food), (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population. An exposure pathway is considered *complete* if evidence exists that all five of these elements are, have been, or will be present in a community. More simply stated, an exposure pathway is considered complete when people are highly likely to be exposed to the chemical of concern. A pathway is considered a *potential* exposure pathway if at least one of the elements is missing but could be found at some point. An *incomplete* pathway is when at least one element is missing and will never be present.

Exposure to DLCs from the Saginaw River can occur from accidentally swallowing (incidental ingestion) soils or sediments; or breathing in (inhalation) dust created from the flood plain soils or sediments; or from the consumption of Saginaw River fish or other organisms that live in the Saginaw River (Table 4).

Table 4 Exposure pathway analysis.

Source(s)	**Chemical**	**Transport**	**Exposure**			**Time Frame**	**Status**
			Point	**Route**	**Population**		
Historic releases to surface water	DLCs	Water and sediment	Fish from the Saginaw River	Ingestion of fish tissue	Fish consumers	Past	Complete
						Present	Complete
						Future	Potential
Historic releases to surface water	DLCs	Water and sediment	Saginaw River Shoreline Soils and Sediments	Incidental ingestion of soil or sediment	People using the Saginaw River and flood plain	Past	Complete
						Present	Complete
						Future	Potential
Historic releases to surface water	DLCs	Water and sediment	Saginaw River Shoreline Soils	Inhalation of dust	People using the Saginaw River and flood plain	Past	Complete
						Present	Complete
						Future	Potential

Exposure to DLCs does not mean that harm to human health will occur. Several additional factors must also be taken into consideration, such as, the amount of DLCs in the soil, sediment, or fish tissue; the quantity of material inhaled or ingested; the number of times a person is exposed to the contaminated material; and how that exposure occurs (swallowing into the digestive system, breathing into the lungs).

Many DLCs that enter a person's blood, organs, and fat will stay in that person for many months to years. On average, it will take one to 12 years for half of the DLCs to leave a person's body (ATSDR 1998, 2000). For 99.9% of the DLCs to leave a person's body, it can take 10 to 120 years. Because these chemicals enter the body and stay for many years, a small amount of exposure to DLCs on a regular basis results in DLCs accumulating in a person's body.

Saginaw River Sediment, Soil, and Dust Pathways
Saginaw River sediments and soils have been documented to contain DLCs. People recreating on the banks or in the Saginaw River may come into contact with soils and sediments contaminated with DLCs. People, particularly children, may unintentionally swallow small amounts of DLC containing soils. Individuals or their pets may unintentionally carry DLC containing soils and sediments to their homes where it may become part of household dust. Unintended daily ingestion of dust contaminated with similar chemicals has been shown to be an important pathway for chemicals entering the human body (Lorber 2007, Fischer et al. 2006, Jones-Otazo et al. 2005). Because these chemicals have contaminated the Saginaw River sediments and riverbank soils for many decades, people using the river have likely been exposed to this source of DLCs.

Saginaw River Fish Consumption Pathways
Based on interviews with 520 people fishing the Saginaw River, MDCH reported people regularly eat fish from the Saginaw River and feed Saginaw River fish to their families (MDCH 2007). Using the reported fish consumption rates from people eating fish from the Saginaw Waters, MDCH calculated middle (50^{th} percentile) and upper-end (95^{th} percentile) rates of fish consumption for six fish consumption patterns (Appendix 4). The rates of fish consumption reported by MDCH are similar to other fish consumption studies in Michigan (West et al. 1989 & 1993, Murray and Burmaster 1994).

Background DLC Exposure Pathways
Every person in the United States is exposed to very small quantities of DLCs. For the average person not in contact with elevated DLC containing materials (e.g., Saginaw River fish), 95% of their DLC exposure comes from the consumption of purchased food. A small percentage of a person's exposure comes from incidental ingestion or inhalation of DLCs. Intake from dermal (skin) exposure to DLCs is extremely small and not a significant pathway for humans.

Toxicological Evaluation

For a given set of conditions, the toxicity of specific DLCs depends on the number and position of the chlorine atoms. Not all DLCs have the same toxicity or ability to cause illness and adverse health effects. However, DLCs are understood to cause adverse health effects through a similar biological mechanism of action. Furthermore, the science indicates that health effects from exposure to multiple DLCs are additive, meaning the health effects are greater than would be expected for a single compound.

People have developed chloracne, a skin disease with severe acne-like pimples, from exposure to high levels of DLCs. Chloracne can persist for years, sometimes clearing only to recur several years later. Changes in blood and urine that may indicate liver damage have occurred in exposed persons. Exposure to high concentrations of DLCs may cause long-term alterations in glucose (blood sugar) metabolism and slight changes in hormone levels (ATSDR 1998).

Observational studies of people accidentally exposed to lower concentrations of DLCs have reported alterations in reproductive and thyroid hormone levels, effects on sperm quality, altered immune system responses in children, and neurodevelopment effects in children (ATSDR 1998, Mocarelli et al. 2008, Weisglas-Kuperus et al. 2000). Because these are observational studies, unequivocal statements about DLC causing these human health effects have not been reached.

DLCs likely contribute to the risk of cancer in humans. EPA has characterized the mixture of DLCs to which people are commonly exposed as "*likely human carcinogens*" (EPA 2000). EPA also has characterized 2,3,7,8-TCDD as a "*human carcinogen*" (EPA 2000). The International Agency for Research on Cancer (IARC) has characterized 2,3,7,8-TCDD as "*carcinogenic to humans*". IARC has stated that due to inadequate information, the other 2,3,7,8 chlorine containing dioxins and furans are "*not classifiable as to their carcinogenicity to humans*." The U.S. Department of Health and Human Services' *National Toxicology Program 9th Report on Carcinogens* (NTP 2001) lists 2,3,7,8-TCDD as a substance "*known to be a human carcinogen*."

Animals are used to model human exposures and study possible health outcomes. Exposure to low levels of DLCs in animal models has resulted in a wide variety of adverse health effects, such as cancer, liver damage, and disruption of the endocrine system. Some animal species, including monkeys, exposed to DLCs during pregnancy had miscarriages. The offspring of animals exposed to DLCs during pregnancy often had birth defects including skeletal deformities, kidney defects, weakened immune responses, reproductive and neurodevelopmental effects (ATSDR 1998). Researchers have used animal models to demonstrate that exposure to DLCs can cause reproductive damage, birth defects, decreased sperm counts, immune suppression, genital malformations, neurobehavioral effects, endometriosis, and behavioral change.

Exposure Scenarios

MDCH expects fish consumption from the Saginaw River to be the dominant DLC exposure pathway to humans from the Saginaw River. MDCH currently does not expect incidental ingestion of Saginaw River flood plain soil/dust to contribute significantly to a person's DLC exposure given that the concentration for the top one-inch of Saginaw River flood plain soils ranged from 0.7 to 144 ppt-$TEQ_{d,f,p\ WHO\ 2005}$. MDCH expects that people will on average be exposed to 6 ppt-$TEQ_{d,f\ WHO\ 1998}$ in soils given that people will spend relatively small percentage of their lifetime on the banks of the Saginaw River. MDCH included the soil/dust DLC concentration of 6 ppt-$TEQ_{d,f\ WHO\ 1998}$ in the background DLC exposure estimates.

MDCH used commonly accepted risk evaluation practices (WDNR 2002, US EPA 2004). MDCH evaluated fish consumption scenarios that are based on reported local fish consumption patterns (MDCH 2007). The MDCH report documented a wide range of fish consumption patterns. MDCH interviewed 102 fishers that reported eating benthic fish (carp, catfish, freshwater drum, suckers) from the Saginaw Waters (Table 5). Sixty-four of these individuals reported that at least 50% of their fish consumption from the Saginaw Waters was benthic fish, and for 43 of these individuals 100% of their fish consumption was benthic fish. MDCH also interviewed 498 individuals that stated they only eat one or more species of sport fish (bluegill, crappie, white bass, largemouth bass, northern pike, salmon, smallmouth bass, trout, walleye, whitefish, yellow perch) from these waters. The most commonly consumed species of sport fish were walleye and yellow perch.

Table 5 Number of fish consumers reporting their percentage of consumption of sport and benthic species of fish from the Saginaw Waters.

Percentage of Fish Meals that were Sport Fish	Percentage of Fish Meals that were Benthic Fish	Number of Saginaw Bay Watershed Fish Consumers per Category
0	100	43
5	95	1
20	80	2
25	75	2
30	70	1
33	67	1
50	50	14
60	40	2
66	34	4
75	25	19
80	20	7
90	10	5
95	5	1
100	0	498

To represent this wide range of fish consumption patterns, MDCH evaluated five fish consumption scenarios (Table 6). MDCH based the Saginaw River fish consumption estimates on reported monthly rates of fish consumption from the Saginaw Waters (MCDH 2007). MDCH based the purchased fish consumption estimates on SBW fish consumers' reported fish consumption from other sources (MDCH 2007). MDCH evaluated adult and child characteristics for each scenario because 79-85% of Saginaw Bay Watershed fish consumers reported that their fish consumption patterns were the same as their family members (MDCH 2007). Additionally, MDCH evaluated both average and frequent fish consumption patterns for each scenario. MDCH based the average fish consumption estimates on the 50th percentile for the corresponding fish consuming populations presented in Appendix 4. MDCH based the frequent fish consumption estimates on the 95th percentile for the corresponding fish consuming populations presented in Appendix 4. MDCH interviewed people who exceeded the 95th

percentile as shown for the 99th percentile values (Appendix 4), thus the 95th percentile estimates do not necessarily represent the maximum exposures from the Saginaw River. MDCH adjusted all fish consumption scenarios to not exceed the total number of fish meals reported in Appendix 4.

MDCH based the DLC concentrations assigned to each meal of Saginaw River fish (Table 6) on measured concentration of DLCs in Saginaw River or Saginaw Bay fish fillets (Appendix 5). MDCH based walleye meal DLC concentrations on measured concentration from the Saginaw Bay and Tittabawassee River, given that walleye are known to migrate between those two waters and no DLC data for walleye from the Saginaw River were available at the time this health consultation was written.

Table 6 Meals per month (mls/mth), grams per day (g/d), and DLC fish meal concentrations for five average and frequent Saginaw River fish consumer scenarios.

Saginaw River Fish Consumer	**Average Fish Consumer 50th percentile**				**Frequent Fish Consumer 95th percentile**				**Average DLC Fish Meal**
Scenarios	**Saginaw River**		**Purchased**		**Saginaw River**		**Purchased**		**Concentrations[a]**
	mls/mth	**g/d**	**mls/mth**	**g/d**	**mls/mth**	**g/d**	**mls/mth**	**g/d**	**ppt-TEQ$_{d,f,p}$ [b]**
70-kg ADULT (227 g/meal)									
Walleye Only	2	15.1	1	7.6	5	37.8	3	22.7	2.6
Catfish Only	2	15.1	1	7.6	7	52.9	3	22.7	16
Carp Only	1.25	9.4	1.25	9.4	2	15.1	3	22.7	420
Mixed Sport	2	15.1	1	7.6	8	60.5	3	22.7	10
Mixed Benthic	2	15.1	1	7.6	7.5	56.7	3.5	26.5	43
28-kg CHILD (113 g/meal)									
Walleye Only	2	7.6	1	3.8	5	18.9	3	11.3	2.6
Catfish Only	2	7.6	1	3.8	7	26.5	3	11.3	16
Carp Only	1.25	4.7	1.25	4.7	2	7.6	3	11.3	420
Mixed Sport	2	7.6	1	3.8	8	30.2	3	11.3	10
Mixed Benthic	2	7.6	1	3.8	7.5	28.3	3.5	13.2	43

[a] Means based on Appendix 5
[b] TEQ calculated using Van den Berg et al. 2005,

The first scenario (*Consumers of Walleye Only*), represents Saginaw River fish consumers who only eat walleye from the Saginaw River. People including yellow perch in their diet would have similar or less risk from DLC exposure given that yellow perch are less contaminated with DLCs than walleye.

The second scenario (*Consumers of Catfish Only*), evaluates the risk to fish consumers that stated they only eat benthic fish species and would choose to eat catfish as those meals of fish (MDCH 2007). Sixty-two percent of minority fishers interviewed by MDCH reported eating locally caught catfish. Based on the available fish tissue DLC data, catfish are the least contaminated benthic species of fish, thus this scenario may represent the low-end of exposure and risk for fish consumers that only eat benthic fish from the Saginaw River.

The third scenario (*Consumers of Carp Only*), evaluates the risk to fish consumers that stated they only eat benthic fish species and that would choose to eat carp as those meals of fish (MDCH 2007). A total of nine individuals stated they eat carp (MDCH 2007). The estimates of the average and frequent fish consumption for people stating they eat carp were lower than the estimates provided by all other fish consuming populations. This lower estimate may be due to the small number of carp consumers interviewed, and may under estimate the upper-end carp consumption rates.

The fourth scenario (*Consumers of a Mixture of Sport Fish*), evaluates the risk to fish consumers that stated they only eat a mixture of sport fish species (bluegill, crappie, white bass, largemouth bass, northern pike, salmon, smallmouth bass, trout, walleye, whitefish, yellow perch), but not benthic fish species.

The fifth scenario (*Consumers of a Mixture of Benthic Fish*), evaluates the risk to fish consumers that stated they eat a mixture of sport and benthic fish species. Benthic fish consumers may be eating various sport fish species in addition to eating benthic fish species.

Cancer Health Assessment
Using the Saginaw River fish consumer scenarios (Table 6), MDCH estimated the incremental lifetime individual cancer risk (upper bound) above background DLC exposures (Table 7). These estimates do not represent reported cancers in the community. All such cancer risks are theoretical and represent upper-end or maximum estimates. Incremental lifetime individual cancer risk level estimates protect sensitive persons; thus, most people who eat Saginaw River fish face less risk than suggested by the estimates, and for some people the risk may even be zero. MDCH considers risk levels exceeding one additional cancer per 100,000 exposed people (1×10^{-5}) to require further consideration. Appendices 6 and 7 provide the equations used to calculate these estimates.

The additional cancer risk from average and frequent consumption of open water species of fish depends on which Saginaw River fish species people eat. MDCH estimates that people eating a mixture of sport fish may have maximal additional cancer risks that range from 6.9 to 27 additional cancers per 100,000 people exposed. The cancer risk estimates are smaller for people only eating yellow perch (range: 0.3 to 1.1 additional cancers per 100,000 people exposed). The maximal cancer risk estimates for people eating two meals of walleye per month (1.8 additional cancers per 100,000 people exposed) are higher than for people only eating yellow perch. MDCH reported that a small segment of SBW fish consumers eat locally harvested walleye at a rate of at least 5 meals per month, which results in maximal cancer risk of 4.5 additional cancers per 100,000 people exposed. The maximal cancer risk continues to increase as people eat the more contaminated sport fish species and it reaches a maximum cancer risk for average and frequent white bass consumer (average consumer [2 meals per month]: 12 additional cancers per 100,000 people exposed, frequent consumer [8 meals per month]: 48 additional cancers per 100,000 people exposed).

The theoretical added cancer risk for those eating the benthic (bottom feeding) fish from the Saginaw River (i.e., carp, catfish, freshwater drum, or suckers) is much greater than 1 in 100,000 for the average consumer (range: 10 to 180 additional cancers per 100,000 people exposed) and for the frequent consumer (range: 36 to 290 additional cancers per 100,000 people exposed).

Table 7 Theoretical incremental lifetime individual cancer risk upper bound estimates for Saginaw River fish consumption scenarios.[a]

Saginaw River Fish Consumption Scenarios	Average Daily DLC TEQ Intake[b]	Theoretical Incremental Lifetime Individual Cancer Risk[c] (upper bound)	Average Daily DLC TEQ Intake[b]	Theoretical Incremental Lifetime Individual Cancer Risk[c] (upper bound)
	pg/kg-bw/d	($x10^{-5}$)	*pg/kg-bw/d*	($x10^{-5}$)
Walleye Only	0.2	1.8	0.6	4.5
Catfish Only	1.4	10	4.8	36
Carp Only	24	180	38	290
Mixed Open Water	0.9	6.9	3.7	27
Mixed Benthic	3.8	29	14	110

[a] Cancer risk estimates presented in this table are two times greater when using the U.S. EPA's cancer potency factor of 0.00015 $(pg/kg\text{-}bw/d)^{-1}$ (U.S. EPA 1997). U.S. EPA cancer assessment of dioxin, including a higher potency factor, is currently under going review.
[b] DLC TEQ daily intake estimates are based on fish consumption rates listed in Table 6 and calculated using the equation in Appendix 6, which represents 30 years of fish consumption averaged over a lifetime (70 years).
[c] Cancer risk estimates are calculated using the DLC TEQ daily intake, a cancer potency value of 0.000075 $(pg/kg\text{-}bw/d)^{-1}$, and the equation in Appendix 7.

Non-Cancer Risk Estimates

MDCH calculated non-cancer risk estimates for adult and child scenarios. The adult scenario evaluates a 70-kg person eating an eight-ounce meal size for a period of 30 years at the meal frequency stated in Table 6. The child scenario evaluates a 28-kg individual eating a four-ounce meal size for a period of 10 years at the meal frequency stated in Table 6. MDCH estimated non-cancer risk over the years of exposure. Using the Saginaw River fish consumer scenarios (Table 6), MDCH estimated daily DLC intakes that included background DLC exposure (Table 8). In background DLC exposure estimates, MDCH included ingestion or inhalation of DLC from air, water, soil, and purchased food (Appendix 8). The estimated DLC daily intakes were compared to the ATSDR DLC minimal risk level (MRL = 1 pg-TEQ/kg/day) as described in Appendices 6 and 7. The

ATSDR MRL represents a daily DLC exposure that is intended to be protective for everyone. The ATSDR DLC MRL is based on the endpoint of developmental behavior (ATSDR 1998). Researchers used an experimental model (female rhesus monkey) to provide insight into human DLC exposures and health effects. Researchers gave female rhesus monkeys a range of DLC exposures with the lowest amount being 120 pg $_{2,3,7,8\text{-}TCDD}$ /kg/day. After 7 months of exposure, researchers allowed the female monkeys to produce offspring and the behaviors of the offspring were documented. Researchers found statistically significant differences in offspring behavior at the lowest concentration. To protect every human including the fetus and young children, ATSDR reduced the concentration of 120 pg $_{2,3,7,8\text{-}TCDD}$ /kg/day to 1 pg $_{2,3,7,8\text{-}TCDD}$ /kg/day to account for the uncertainty associated with using animal models and for variation in human sensitivity (ATSDR 1998).

Daily DLC intakes that slightly exceed the MRL (i.e. Hazard Quotients greater than 1.0) does not necessarily mean that negative health effects will occur. However, the greater the exceedance of the MRL, the greater the potential for health effects and the need that actions be taken to reduce the DLC exposure levels.

Table 8 Non-cancer risk estimates for Saginaw River fish consumption scenarios.

Saginaw River Fish Consumption Scenarios		**Non-Cancer Risk Hazard Quotients**[a]	
		Fish Consumption Rate	
		Average	*Frequent*
Walleye Only	*Adult*	1.0	1.8
	Child	1.6	2.6
Catfish Only	*Adult*	3.8	12
	Child	5.1	16
Carp Only	*Adult*	56	90
	Child	71	112
Mixed Sport Fish	*Adult*	2.5	8.9
	Child	3.6	12
Mixed Benthic	*Adult*	9.6	35
	Child	12	44

[a] The hazard quotients are calculated based on fish consumption rates in Table 6, the ATSDR minimal risk level (MRL) of 1 pg/kg-bw/d, and the equations in Appendices 6 and 7. The daily DLC-TEQ intake (pg/kg/-bw/d) is the same number as the hazard quotient because the ATSDR MRL is 1 pg/kg-bw/d. Fish consumption is assumed to occur over at least one year.

MDCH estimates non-cancer risk (i.e., hazard quotients (HQ)) for adults and children eating benthic (i.e., carp, catfish, freshwater drum, or suckers) fish from the Saginaw River to be much greater than 1 for the average (range of HQs: 3.6 - 70) and frequent consumer (range of HQs: 12 - 111).

The non-cancer risk for adult and child consumers of Saginaw River sport fish depends on the species people eat. MDCH estimates that DLC intake for adults eating a mixture of sport fish species exceed the ATSDR MRL by 2.5 - 8.9 times. MDCH estimates that children eating a mixture of sport fish species exceed the ATSDR MRL by 3.6 - 12 times. The non-cancer risk estimates are less than one for all people that only eat yellow perch. For adults who only eat walleye twice per month, MDCH finds minimal non-cancer risk. A small segment of SBW fish consumers eat walleye at a rate of at least 5 meals per month (MDCH 2007). Adult (HQ: 1.8) and child (HQ: 2.6) frequent walleye consumers have elevated non-cancer risk compared to the ATSDR MRL. Non-cancer risk continues to increase as people eat the more contaminated sport fish species and reaches a maximum non-cancer risk for adults eating white bass (average consumer [2 meals per month, meal size: 227grams] HQ: 4; frequent consumer [8 meals per month, meal size: 227 grams] HQ: 15). For the child scenario, the maximum non-cancer risk for white bass consumers (average consumer [2 meals per month, meal size: 113 grams] HQ: 5.5; frequent consumer [8 meals per month, meal size: 113 grams] HQ: 20)

Description of Uncertainties

MDCH describes the uncertainties in risk estimates to provide the public an understanding that risk estimates are not absolute numbers but represent unbiased and accurate estimates given the available science and may change as new scientific information is obtained. MDCH has the responsibility to provide information that is protective for all people. Therefore, where uncertainty exists, MDCH errs on the side of caution.

The following factors may introduce uncertainty into exposure estimates:

1. MDCH used Saginaw Bay fish fillet DLC concentrations to represent likely concentration in fish fillets from the Saginaw River. Fish from the Saginaw Bay may have different amounts of DLCs than those found in the Saginaw River. Saginaw River fish are closer to DLC sources. Because not all open water or benthic fish species have been analyzed for DLCs, MDCH used fish fillets with measured DLC concentrations to represent unanalyzed fish fillets with similar life histories.

2. The broad range of DLC concentrations found in carp fillets suggests that people eating carp will have very different amounts of DLC exposure depending on the carp that they eat. Based on the 2004 carp data from the Saginaw River and Bay, seven carp fillets ranged between 2-8 ppt-TEQ, nine carp fillets ranged between 20-80 ppt-TEQ, and 3 ranged between 1,500-3,000 ppt-TEQ.

3. The number of riverbank soil DLC measurements was limited relative to the large area to be characterized.

4. Saginaw River specific information has not been collected regarding the range of possible ways in which people interact or use riverbank soils.

5. MDCH did not estimate risk for the upper-end 1% of interviewed fish consumers. MDCH estimated consumption based on interviews of people fishing the Saginaw Waters, thus the upper-end 99^{th} -percentile fish consumption estimates are reported data and not theoretical estimates.

The following factors may introduce uncertainty into risk estimates:

1. The WHO has changed the mammalian toxic equivalency factors. The National Academies of Science (NAS) committee that evaluated DLCs, states "Even with the inherent uncertainties, the [NAS] committee concludes that the toxic equivalency factor methodology provides a reasonable, scientifically justifiable, and widely accepted method to estimate the relative potency of DLCs" (National Research Council of the National Academies 2006).

2. The description of the cancer-causing potency of DLCs to humans is often debated. National Toxicology Program (NTP) and the International Agency for Cancer Research (IARC) have stated that 2,3,7,8-TCDD is a human carcinogen (DHHS 2005, McGregor et al. 1998). The ATSDR *Public Health Statement for Chlorinated Dibenzo-p-dioxins* (CDDs) (http://www.atsdr.cdc.gov/toxprofiles/phs104.html) states:

   "The Department of Health and Human Services (DHHS) has determined that it is reasonable to expect that 2,3,7,8-TCDD may cause cancer," and "the [US] EPA has determined that 2,3,7,8-TCDD is a possible human carcinogen when considered alone and a probable human carcinogen when considered in association with phenoxy herbicides and/or chlorophenols. The [US] EPA has determined also that a mixture of CDDs with six chlorine atoms (4 of the 6 chlorine atoms at the 2, 3, 7, and 8 positions) is a probable human carcinogen."

3. Estimates of the cancer-causing potency of DLCs vary between methods and data sources used to quantify DLC cancer potency. The current cancer potency factor used by Michigan is 75,000 $(mg/kg/day)^{-1}$. The current cancer potency factor used by the U.S. EPA is 150,000 $(mg/kg/day)^{-1}$ (U.S. EPA 1997). A range of cancer potency factors proposed by other state or federal government agencies (See Appendix 9) are 0.35 times less to 13.3 times greater than the current Michigan cancer potency factor. The net change on the upper bound additional incremental cancer risk estimates reported in this health consultation is provided in (Appendix 9).

4. Non-cancer risk daily intake screening values range from 1 to 2 pg/kg/day. The ATSDR MRL is 1 pg/kg/day and includes a safety factor of 100. The World Health Organization (WHO) provides a 70 pg/kg/month screening value that represents a daily intake of 2 pg/kg/day (JECFA 2001). The WHO includes a safety factor of 10.

5. For cancer risk estimates, MDCH used a value of 30 years of fish consumption, which is an intermediate value for sport fish consumers in the Great Lakes region (Falk et al. (1999). Falk et al. (1999) reports people consuming sport fish for 59 years. The greater the number years consuming contaminated fish, the higher the cancer risk estimates become.

Children's Health Considerations

MDCH recognizes that infants and children could be more vulnerable than adults to chemical exposures. Children weigh less than adults, which could result in children having more chemical per unit of body weight than adults, when exposed to a similar amount of chemical. The developing body systems of children can sustain permanent damage if toxic levels of exposure occur.

MDCH documented that 422 children under the age of 15 years and 643 adult females were living in the homes of Saginaw Bay Watershed fish consumers and that these women of child bearing age and children were likely eating the locally caught fish from the Saginaw Waters (MDCH 2007). Based on responses from fish consumers in the MDCH study, 79–85% responded that their fish consumption patterns were the same as the people living in their home (MDCH 2007). Depending on the water body being fished, 40-59% respondents were 40 years old or younger (MDCH 2007). MDCH concludes that childhood and fetal exposure to elevated concentration of DLC from Saginaw River fish is occurring. MDCH evaluated a child scenario for non-cancer health risks. On the basis of this child exposure scenario, children who eat fish from the Saginaw River have higher levels of risk than adults even though the child is assumed to eat half the quantity of contaminated fish. MDCH did not directly evaluate fetal exposure, but expects fetal exposure and risk to be equal or greater than the child risk estimates reported in this health consultation.

Cancer risk estimates typically are not conducted for children given that the assessment methodology averages exposure over an entire lifetime (70 years). MDCH recognizes that exposures at an earlier age may begin a carcinogenic process sooner, resulting in the possibility of cancer occurring at younger ages. MDCH further recognizes that babies exposed in the womb and infants exposed through breastfeeding may receive relatively high amounts of DLC. MDCH used conservative estimated of DLC to ensure that the most sensitive individuals are protected.

Conclusions

MDCH concludes that many of the reported past and current Saginaw River fish consumption patterns are a *public health hazard* due to associated DLC exposures. MDCH concludes that past DLC exposures from consumption of Saginaw River fish were similar to or greater than current DLC exposures. MDCH has issued a fish consumption advisory on the Saginaw River since the early 1980s. Fish consumption advisories are necessary for people who eat fish from the Saginaw River to allow fish consumers the option of minimizing their DLC exposures and associated risks.

Recommendations

1. People who eat fish from the Saginaw River should follow the *Michigan Family Fish Consumption Guide.*
2. Additional DLC (dioxins, furan, co-planar PCBs) fish fillet data are needed on all Saginaw River species other than carp.
3. Efforts should be undertaken to make the Michigan fish consumption guidance more available to women of childbearing age, caretakers for young children, and frequent consumers of Saginaw River fish within the Saginaw Bay Watershed.
4. Efforts should be undertaken to ensure Michigan fish consumption guidance for the Saginaw River is consistent with the finding of this health consultation.

Public Health Actions

1. MDCH will continue to issue its Michigan Family Fish Consumption Guide.
2. MDEQ will continue monitoring fish from the Saginaw River, and MDCH will request that the MDEQ analyze less frequently tested fish species for DLCs and include additional co-planar PCB analyses.
3. MDCH will continue to undertake outreach and education efforts to fish consumers and the sensitive population of the Saginaw Bay Watershed.
4. MDCH will have discussions with the MDEQ and the Michigan Fish and Wild Game Consumption Advisory Committee (FAWCAC) regarding ensuring advice in the 2008 Michigan Family Fish Consumption Guide is consistent with the finding in this health consultation.

If any citizen has additional information or health concerns regarding this health consultation, please contact MDCH’s Division of Environmental Health at 1-800-648-6942.

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Certification

The Michigan Department of Community Health prepared this Health Consultation, Evaluation Of Saginaw River Dioxin Exposures And Health Risks, under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). At the time this Health Consultation was written, it was in accordance with the approved methodologies and procedures.

Technical Project Officer, Cooperative Agreement Team, SPAB, DHAC, ATSDR

The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

Team Leader, Cooperative Agreement Team, SPAB, DHAC, ATSDR

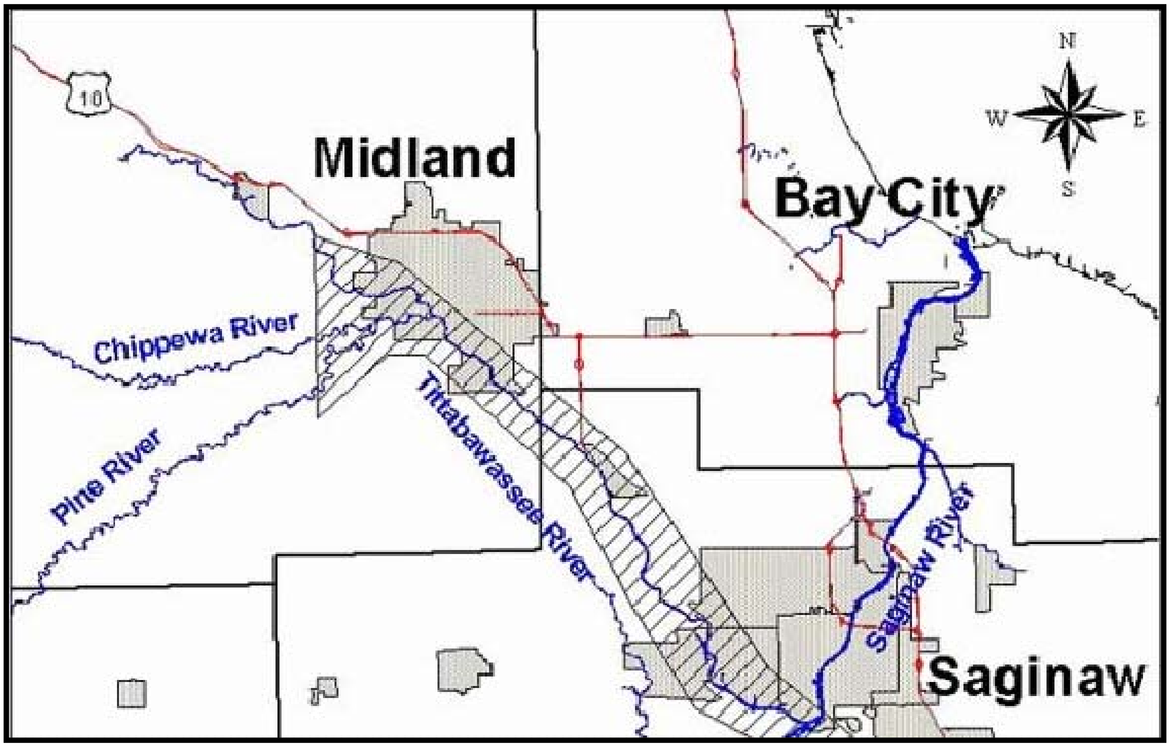

Figure 2. Map of the Tittabawassee and Saginaw Rivers.

Appendix 1 Petition Letter**.**

Dr. Howard Frumkin
Office of the Director, NCEH/ATSDR
Century Center
1825 Century Boulevard
Atlanta, GA 30345
April 10, 2006
Petition for Health Consultation -Saginaw River Saginaw County Michigan
Dear Dr. Frumkin,
We are writing on behalf of our organizations and as individual residents to petition the Agency for Toxics Substances and Disease Registry for a public health assessment regarding potential public health hazards in Saginaw County and Bay County Michigan, along the length of the Saginaw River from its confluence with the Tittabawassee River to the Saginaw Bay of Lake Huron and associated with the extensive and serious dioxin-furan contamination found in the sediments of the Saginaw River. The primary source of this dioxin-furan contamination is the Dow Chemical Company.
Our petition is prompted by the following facts, which have emerged over the last few years:

ATSDR and Michigan Department of Community Health (MDCH) already deemed the Tittabawassee River floodplain community merited a health assessment because of high levels of dioxin -furans in the Tittabawassee River and floodplain.

The contaminated sediments and soils of the Tittabawassee River and floodplain are the source of dioxin to the Saginaw River.

US Environmental Protection Agency, US Army Corp of Engineers and the Michigan Department of Environmental Quality sampling have all revealed sediments of the Saginaw River to have high concentrations of dioxin. The highest concentration found to date is 16,000 ppt., although levels of 11,000 ppt, 8,000ppt, 6000ppt and 3,000ppt have been measured throughout the Saginaw River.

During the late summer of 2005 Michigan Department of Community Health and Michigan Department of Environmental Quality posted fish advisories the entire length of the Saginaw River because of dioxin contamination.

Dow Chemical's RCRA Corrective Action license lists the Saginaw River as an area subject to response and cleanup activities because of the high levels of dioxin.

There are great number of subsistence anglers (men and women) along the Saginaw River. Many of these residents are people of colors who may also be indigent and who rely on the fish from these contaminated waters to nourish their families. Several reports have documented the continued consumption of fish by area residents.

In the summer months the Saginaw River is heavily fished by migrant workers

The Saginaw River travels north through the heavily populated communities of Saginaw and Bay City Michigan. Numerous fishing docks, launch sites and public parks permit easy access to the river and contact with contaminated sediments, soils and fish. Many people own homes or live in communities that border the Saginaw River.

The science supporting the link between dioxins and human health effects is strong and growing. It is time for a public health assessment by ATSDR and appropriate protective actions by federal, state and local agencies to prevent further exposures to dioxin and to assess its impact on residents along the Saginaw River.

The data on the Saginaw River is simply the latest in a long line of disclosures about dioxin contamination in the Saginaw Bay Watershed. Further, rather than taking action to protect the public from the serious soil contamination documented in the sampling of sediments in the Saginaw River, or moving quickly to characterize the extent of the dioxin contamination, the State of Michigan instead met with Dow for 8 months of private discussions. These discussions did not include anyone from the Michigan Department of Public Health or other agencies whose role it is to solely protect public health. During those discussions interim response and cleanup activities were stalled. Therefore exposures continue. When they emerged from these meetings, the agreed upon "Framework between Dow and DEQ only tangentially addressed the Saginaw River and with the exception of the signage little has been done to address the public health implications of these high levels of dioxin. This continues to be the case to date.

It is abundantly clear that significant levels of dioxins are present in the river sediments of communities along the Saginaw River. These contaminants may be ingested through fish, consumed in other food, absorbed through dermal contact with sediments and inhaled. It is time for a public health assessment by ATSDR and appropriate protective actions by federal, state and local agencies to prevent further exposures to dioxin and to prevent negative health in the community.

Appendix 2 Saginaw River DLC Riverbank Surface Soil Concentrations.[1]

Sample ID	CDD/CDF	co-PCBs	Total	Sample ID	CDD/CDF	co-PCBs	Total
	ppt-TEQ$_{WHO\ 2005}$				**ppt-TEQ$_{WHO\ 2005}$**		
FP1	1.1	0.53	1.6	FP91	140	3.6	144
FP2	15	0.81	15.8	FP95	8.3	0.29	8.6
FP3	0.79	0.49	1.3	FP99	7.5	1.7	9.2
FP4	7.3	11	18.3	FP103	1.6	0.075	1.7
FP5	3.1	6	9.1	FP104	40	1.9	41.9
FP6	2.3	0.61	2.9	FP105	0.96	0.059	1.0
FP10	3.1	0.33	3.4	FP106	0.8	0.14	0.9
FP14	3.2	0.32	3.5	FP110	3.9	0.32	4.2
FP18	2.1	0.29	2.4	FP111	3.6	0.8	4.4
FP22	3.6	0.22	3.8	FP112	3.5	1.2	4.7
FP26	1.9	0.2	2.1				
FP27	28	0.3	28.3	**Minimum**			**0.7**
FP31	1.6	0.029	1.6	**Maximum**			**144**
FP32	0.81	0.58	1.4				
FP33	0.76	0.64	1.4				
FP34	0.72	0.028	0.7				
FP38	16	0.26	16.3				
FP41	2.1	0.025	2.1				
FP45	14	0.21	14.2				
FP49	12	0.23	12.2				
FP50	12	0.23	12.2				
FP54	2.3	0.06	2.4				
FP58	1.3	0.039	1.3				
FP59	1.3	0.2	1.5				
FP63	64	0.039	64.0				
FP67	7.1	0.07	7.2				
FP71	43	31	74.0				
FP75	5.8	0.12	5.9				
FP79	14	0.36	14.4				
FP83	2.8	0.23	3.0				
FP87	0.38	0.43	0.8				
FP91	140	3.6	144				

[1] Michigan Department of Environmental Quality. 2006. Dioxin-like toxicity in the Saginaw Bay Watershed Great Lakes National Program Office Grant project # GL965334010 and PBDE distribution in the Saginaw Bay Watershed Great Lakes National Program Office Grant project # GL96558601-0. Final Report. Prepared by : Allan B. Taylor, Deborah R. MacKenzie-Taylor, Arthur Ostaszewski, John M. McCabe May 2, 2006 Revised August 31, 2006.

Appendix 3 DLC Fish Tissue Concentrations

Table 1. Individual DLC fish fillet concentrations for fish from the Saginaw Bay, Saginaw River, and Tittabawassee River.[c]

Collection Date	Location	Species	Sex	Length cm	Weight g	Sample Type[a]	Dioxins (D) Furans (F)	Co-Planar[b] PCBs (P)	Total $_{D/F/P}$[b]
							ppt-TEQ$_{WHO\ 2005}$		
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	M	43.5	900	Fs	6.77	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	46	820	Fs	8.73	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	44.5	880	Fs	5.85	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	M	50.5	1480	Fs	16.17	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	52	1660	Fs	11.83	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	53.5	1500	Fs	7.09	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	55	1480	Fs	5.15	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	59	1920	Fs	11.29	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	60	1960	Fs	9.84	na	na
10/21/1999	Saginaw Bay, near Saginaw River mouth	Channel Catfish	F	60	2100	Fs	22.03	na	na
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish		35.7	480	Fs	7.65	9.8	17.5
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish		39	540	Fs	4.28	6.3	10.6
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish	M	37.2	510	Fs	9.50	7.8	17.3
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish		37.5	530	Fs	3.78	7.0	10.8
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish		42.2	610	Fs	2.87	5.9	8.8
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish		48	1150	Fs	4.92	12.7	17.6
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish		50.3	1220	Fs	5.51	15.5	21.1
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish	F	51.9	1360	Fs	5.44	13.8	19.2
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish	F	52.2	1660	Fs	8.17	9.5	17.6
9/10/2004	Saginaw Bay, Bay Port	Channel Catfish	F	63.6	2720	Fs	5.09	10.6	15.7
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	M	51.4	1440	F	7.28	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	M	53.7	2300	F	13.13	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	M	54.6	1880	F	7.09	na	na

Collection Date	Location	Species	Sex	Length cm	Weight g	Sample Type[a]	Dioxins (D) Furans (F)	Co-Planar PCBs (P)	Total $_{D/F/P}$
								ppt-TEQ$_{WHO\ 2005}$	
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	F	56.2	1880	F	10.78	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	F	58.7	2020	F	13.38	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	M	58.5	1960	F	14.83	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	F	60	2420	F	11.58	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	F	63	2860	F	12.17	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	F	71.2	3560	F	26.36	na	na
6/4/1993	Saginaw Bay, near Saginaw River mouth	Lake Trout	F	71.7	3880	F	12.80	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		46.5	1000	F	1.53	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		43	740	F	0.86	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		41.5	710	F	1.92	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		45	830	F	0.39	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		46.5	1130	F	1.19	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		52.5	1400	F	0.47	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		56.5	1600	F	2.21	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		57.5	1820	F	1.78	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		53	1660	F	1.70	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		58.5	1870	F	5.95	na	na
9/10/2004	Saginaw Bay, Bay Port	White Bass	M	21.8	185	F	1.68	3.6	5.3
9/10/2004	Saginaw Bay, Bay Port	White Bass	M	22.5	205	F	2.76	5.1	7.9
9/10/2004	Saginaw Bay, Bay Port	White Bass	M	21.5	170	F	6.40	4.9	11.3
9/10/2004	Saginaw Bay, Bay Port	White Bass	F	23.2	240	F	4.30	5.8	10.1
9/10/2004	Saginaw Bay, Bay Port	White Bass		24.6	235	F	2.17	4.9	7.1
9/10/2004	Saginaw Bay, Bay Port	White Bass	F	25.8	310	F	2.00	5.6	7.6
9/10/2004	Saginaw Bay, Bay Port	White Bass	F	30.2	520	F	6.62	16.1	22.7
9/10/2004	Saginaw Bay, Bay Port	White Bass	M	29.6	430	F	7.59	14.5	22.1

Collection Date	Location	Species	Sex	Length cm	Weight g	Sample Type[a]	Dioxins (D) Furans (F)	Co-Planar PCBs (P)	Total $_{D/F/P}$
								ppt-TEQ$_{WHO\ 2005}$	
9/10/2004	Saginaw Bay, Bay Port	White Bass	F	30.1	480	F	5.65	8.5	14.2
9/10/2004	Saginaw Bay, Bay Port	White Bass	M	36.4	630	F	14.74	49.9	64.6
9/25/1991	Saginaw Bay, Au Gres	Carp	M	58	2610	Fs	1.52	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	F	60.6	3900	Fs	3.78	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	M	51	2250	Fs	7.68	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	F	54.9	3300	Fs	8.57	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	F	50.8	2510	Fs	11.74	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	M	63.5	4110	Fs	8.82	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	M	59.7	3450	Fs	14.99	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	M	52.8	2740	Fs	16.87	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	M	61.8	3550	Fs	24.36	na	na
9/25/1991	Saginaw Bay, Au Gres	Carp	M	62.3	3380	Fs	33.30	na	na
10/1/1991	Saginaw Bay, Fish Point	Carp		58	3030	Fs	15.94	na	na
10/1/1991	Saginaw Bay, Fish Point	Carp		60	3600	Fs	29.11	na	na
10/1/1991	Saginaw Bay, Fish Point	Carp		66	4300	Fs	31.91	na	na
10/1/1991	Saginaw Bay, Fish Point	Carp		61.5	4530	Fs	42.57	na	na
10/1/1991	Saginaw Bay, Fish Point	Carp		65.5	4820	Fs	106.14	na	na
9/10/2004	Saginaw Bay, Bay Port	Carp	M	55.7	2270	Fs	6.06	24.8	30.8
9/10/2004	Saginaw Bay, Bay Port	Carp	F	56.7	2520	Fs	4.87	20.8	25.6
9/10/2004	Saginaw Bay, Bay Port	Carp	M	56.2	2530	Fs	2.55	4.8	7.4
9/10/2004	Saginaw Bay, Bay Port	Carp	M	52.8	2190	Fs	7.11	19.1	26.3
9/10/2004	Saginaw Bay, Bay Port	Carp	M	60.7	3180	Fs	9.72	39.9	49.6
9/10/2004	Saginaw Bay, Bay Port	Carp	F	63.8	3960	Fs	16.56	59.9	76.4
9/10/2004	Saginaw Bay, Bay Port	Carp	F	69	4340	Fs	2.21	1498	1500
9/10/2004	Saginaw Bay, Bay Port	Carp	F	62.7	4170	Fs	40.45	6.7	47.1

Collection Date	Location	Species	Sex	Length cm	Weight g	Sample Type[a]	Dioxins (D) Furans (F)	Co-Planar PCBs (P)	Total $_{D/F/P}$
							ppt-TEQ$_{WHO\ 2005}$		
9/10/2004	Saginaw Bay, Bay Port	Carp	F	66.9	4780	Fs	20.70	50.9	71.6
7/15/1992	Saginaw County, Crow Island	Carp	F	74	6310	Fs	20.79	na	na
7/15/1992	Saginaw County, Crow Island	Carp	F	56	3000	Fs	32.05	na	na
7/15/1992	Saginaw County, Crow Island	Carp	F	69	6400	Fs	35.32	na	na
7/15/1992	Saginaw County, Crow Island	Carp		54	2300	Fs	43.68	na	na
7/15/1992	Saginaw County, Crow Island	Carp	F	65.5	5130	Fs	50.01	na	na
7/15/1992	Saginaw County, Crow Island	Carp	F	64.5	5460	Fs	56.57	na	na
8/9/2004	Saginaw River	Carp	M	36.8	730	Fs	2.49	0.1	2.6
8/9/2004	Saginaw River	Carp	M	49.2	1650	Fs	11.48	9.1	20.6
8/9/2004	Saginaw River	Carp	F	51.2	1740	Fs	3.61	3.6	7.2
8/9/2004	Saginaw River	Carp	M	51.1	1750	Fs	6.61	31.7	38.3
8/9/2004	Saginaw River	Carp	F	51.7	2060	Fs	3.31	2.6	5.9
8/9/2004	Saginaw River	Carp	M	58.6	2440	Fs	1.66	1.7	3.4
8/9/2004	Saginaw River	Carp	F	58.7	2950	Fs	3.98	1.7	5.7
8/9/2004	Saginaw River	Carp	M	58.2	2570	Fs	2.67	2.0	4.7
8/9/2004	Saginaw River	Carp	M	65.1	3280	Fs	22.15	2768	2791
8/9/2004	Saginaw River	Carp	M	62.1	3710	Fs	32.73	2988	3020
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	M	22	120	F	NA	0.02	0.02
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	F	24.3	190	F	0.31	0.02	0.33
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	F	21.8	130	F	0.59	0.00	0.59
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	F	23.4	140	F	0.29	0.02	0.30
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	F	21.8	105	F	0.49	0.02	0.51
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	M	20	100	F	1.59	0.07	1.66
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	M	22.5	135	F	0.33	0.02	0.35
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	F	21	125	F	0.81	0.05	0.86

Collection Date	Location	Species	Sex	Length cm	Weight g	Sample Type[a]	Dioxins (D) Furans (F)	Co-Planar PCBs (P)	Total $_{D/F/P}$
							ppt-TEQ$_{WHO\ 2005}$		
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	F	24.5	170	F	0.95	0.13	1.08
9/10/2004	Saginaw Bay, Bay Port	Yellow Perch	M	28.7	315	F	0.63	0.07	0.71
9/10/2004	Saginaw Bay, Bay Port	Walleye	M	40.1	520	F	1.26	0.15	1.41
9/10/2004	Saginaw Bay, Bay Port	Walleye	M	40.3	520	F	0.42	0.05	0.46
9/10/2004	Saginaw Bay, Bay Port	Walleye	M	40.2	590	F	0.61	0.10	0.71
9/10/2004	Saginaw Bay, Bay Port	Walleye	M	41	600	F	0.78	0.11	0.89
9/10/2004	Saginaw Bay, Bay Port	Walleye	F	40.8	620	F	0.69	0.11	0.80
9/10/2004	Saginaw Bay, Bay Port	Walleye	M	42.3	670	F	0.77	0.18	0.95
9/10/2004	Saginaw Bay, Bay Port	Walleye	F	48.2	990	F	1.06	0.19	1.24
9/10/2004	Saginaw Bay, Bay Port	Walleye	M	53.2	1310	F	7.73	1.35	9.08
9/10/2004	Saginaw Bay, Bay Port	Walleye	F	55.7	1700	F	1.79	0.39	2.18
9/10/2004	Saginaw Bay, Bay Port	Walleye	F	57.5	2120	F	2.76	0.56	3.32
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		46.5	1000	F	1.53	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		43	740	F	0.86	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		41.5	710	F	1.92	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		45	830	F	0.39	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		46.5	1130	F	1.19	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		52.5	1400	F	0.47	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		56.5	1600	F	2.21	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		57.5	1820	F	1.78	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		53	1660	F	1.70	na	na
9/27/1994	Saginaw Bay, near Saginaw River mouth	Walleye		58.5	1870	F	5.95	na	na
10/30/1992	Tittabawassee River	Walleye		41.9	862	F	3.9	na	na
10/30/1992	Tittabawassee River	Walleye		54.6	1497	F	3.5	na	na
4/2/2003	Tittabawassee River	Walleye	M	41.1	710	F	2.2	na	na

Collection Date	Location	Species	Sex	Length cm	Weight g	Sample Type[a]	Dioxins (D) Furans (F)	Co-Planar PCBs (P)	Total D/F/P
							ppt-TEQ$_{WHO\ 2005}$		
4/2/2003	Tittabawassee River	Walleye	M	42.8	710	F	2.4	na	na
4/2/2003	Tittabawassee River	Walleye	M	42.4	690	F	1.5	na	na
4/2/2003	Tittabawassee River	Walleye	M	43.7	800	F	2.4	na	na
4/2/2003	Tittabawassee River	Walleye	M	44.7	920	F	4.7	na	na
4/2/2003	Tittabawassee River	Walleye	M	47	1050	F	2.1	na	na
4/2/2003	Tittabawassee River	Walleye	M	47	1160	F	3.8	na	na
4/2/2003	Tittabawassee River	Walleye	M	49.8	1190	F	2.3	na	na
4/2/2003	Tittabawassee River	Walleye	M	49.6	1120	F	5.4	na	na
4/2/2003	Tittabawassee River	Walleye	M	51.2	1180	F	5.9	na	na
7/5/2000	Tittabawassee River	Walleye	M	36.8	450	F	2.8	na	na
7/5/2000	Tittabawassee River	Walleye	M	37.1	410	F	2.2	na	na
7/5/2000	Tittabawassee River	Walleye	M	37.2	430	F	1.3	na	na
7/5/2000	Tittabawassee River	Walleye	M	36.7	410	F	2.3	na	na
7/5/2000	Tittabawassee River	Walleye		37	430	F	1.1	na	na
7/5/2000	Tittabawassee River	Walleye		37.8	430	F	1.9	na	na
7/5/2000	Tittabawassee River	Walleye	M	38.7	500	F	2.4	na	na
7/5/2000	Tittabawassee River	Walleye	M	38.4	520	F	3.2	na	na
7/5/2000	Tittabawassee River	Walleye	F	39.7	550	F	2.3	na	na
7/5/2000	Tittabawassee River	Walleye	F	39.7	500	F	1.9	na	na

[a] "F" is fillet skin-on and "Fs" is fillet skin-off.
[b] na: information was not available.
[c] Data acquired from the Michigan Department of Environmental Quality, contact Joseph Bohr, Lansing Michigan.

Table 2. Summary of the mean (range) of fish tissue dioxin (D), furan (F), and co-planar PCB (P) data, years of sample collection, range of fish lengths, and range of fish weights reported in Appendix 3, Table 1.

Species	**Water Body**[b]	**Years**	**Length Range** cm	**Weight Range** grams	**TEQ D/Fs** ppt	**TEQ Co-PCBs (P)** ppt	**Total TEQs D/F/P** ppt
Catfish	SB	1999, 2004	37-64	510-2,720	8.1 (2.9-22)	9.9 (5.9-16)	16 (8.8-21)
Carp	SB & SR	1991, 1992, 2004	37-74	730-6,400	20 (1.5-106)	400 (0.09-2,988)	420[a] (na)
Lake Trout	SB	1993	51-72	1,440-3,880	12.9 (7.1-26)	na	na
White Bass	SB	2004	22-36	170-630	5.8 (2.0-15)	12 (3.6-50)	17 (5.3-65)
Yellow Perch	SB	2004	20-29	100-315	0.67 (0.3-1.6)	0.043 (0-0.13)	0.71 (0.3-1.7)
Walleye	SR, SB, TR	1993, 1994, 2000, 2003, 2004	37-59	410-2,120	2.3 (0.4-7.7)	0.32 (0.05-1.3)	2.6[a] (na)

[a] Total TEQ for carp and walleye are the sum of the average TEQ concentrations for D/Fs and co-PCBs because not all samples were analyzed for co-PCBs.

[b] SB= Saginaw Bay
SR= Saginaw River
TR= Tittabawassee River

Appendix 4 Calculation of the 50th, 95th, and 99th percentiles for meals per month from the Saginaw Waters.

MDCH reported that the vast majority (82%) of people eating fish caught from the Saginaw River, Saginaw Bay, Tittabawassee River, or Shiawassee River live within the county that the water body flows through or in an immediately adjacent county (MDCH 2007). MDCH also reported that the most commonly fished waters were the Saginaw Bay, Saginaw River, and Tittabawassee River. Out of the 907 fish consumers interviewed, 634 people reported fish consumption from the local water body they were fishing at the time of the interview and were asked by MDCH staff to provide estimates of their average monthly fish consumption rates and favorite fish species to eat from that water body. MDCH asked the 634 fish consuming participants to report their typical fish consumption rates from other sources. These other sources could include purchased fish or fish caught from other local water bodies including the Saginaw Bay, Saginaw River, or Tittabawassee River. For example, a person fishing the Saginaw River would include in the category of "other fish consumption" their consumption of fish from the Tittabawassee River, Saginaw Bay, and a restaurant.

Using the average monthly fish consumption responses from the 634 SBW fish consumers, MDCH calculated the middle (50th percentile) and two upper-end (95^{th}, 99^{th} percentile) average monthly fish consumption rates from the water body being fished at the time of the interview (*Water Body Specific Fish Consumption Rates*). Also, MDCH calculated the middle (50th percentile) and two upper-end (95^{th}, 99^{th} percentile) average monthly fish consumption rates for the other sources (*Other Fish Consumption Rates*), as well as the combined estimates of these monthly fish consumption rates (*Combined Fish Consumption Rates*) (Tables 1–6).

MDCH calculated these three types of monthly fish consumption rates (*Water Body Specific, Other, Combined*) for each of six types of Saginaw Bay Watershed fish-consuming populations identified from the MDCH fish consumption study. The first population (*Walleye Only*) of fish consumers only ate walleye (Table 1). The MDCH study had a total of 338 *Walleye Only* fish consumers, which MDCH used to estimate this populations middle and upper-end average monthly fish consumption rates. The second population (*Walleye and Perch Only or Perch Only*; N=188) of fish consumers was selected because they reported only eating walleye and yellow perch or only eating yellow perch (Table 2). The third population (*Sport Fish*; N=96) of fish consumers was selected because they reported eating one or more species of the sport fish in addition to walleye or yellow perch (bluegill, crappie, white bass, largemouth bass, northern pike, salmon, smallmouth bass, trout, whitefish), but did not eat any benthic fish species (carp, catfish, freshwater drum, suckers) (Table 3). The fourth population (*Benthic Fish*; N=66) of fish consumers was selected because they reported eating one or more species of benthic fish (Table 4). The fifth population (*Catfish Consumers*, N=50) of fish consumers stated they include catfish in their diet (Table 5). The sixth population (*Carp Consumers*, N=9) of fish consumers stated they include carp in their diet (Table 6).

Table 1. Meals per month of fish consumption for Saginaw Bay Watershed fish consumers (number of consumers) that eat only walleye.

Walleye Only Consumers (N=338)	**Meals Eaten Each Month**		
	Population Percentiles		
	50th	**95th**	**99th**
Other Fish Consumption Rates	1.0	3.0	5.0
Water Body Specific Fish Consumption Rates	2.0	6.0	15
Combined Fish Consumption Rates	3.0	8.0	16

Table 2. Meals per month of fish consumption for Saginaw Bay Watershed fish consumers (number of consumers) that eat only walleye and perch or only perch.

Walleye and Perch or Perch Only Consumers (N=188)	**Meals Eaten Each Month**		
	Population Percentiles		
	50th	**95th**	**99th**
Other Fish Consumption Rates	1.0	2.5	4.1
Water Body Specific Fish Consumption Rates	2.0	8.0	20
Combined Fish Consumption Rates	3.0	9.0	20

Table 3. Meals per month of fish consumption for Saginaw Bay Watershed fish consumers (number of consumers) that eat a variety of sport fish species.

Sport fish Consumers (N=96)	**Meals Eaten Each Month**		
	Population Percentiles		
	50th	**95th**	**99th**
Other Fish Consumption Rates	1.0	4.0	5.1
Water Body Specific Fish Consumption Rates	2.0	10	20
Combined Fish Consumption Rates	3.0	11	21

Table 4. Meals per month of fish consumption for Saginaw Bay Watershed fish consumers (number of consumers) that include benthic fish in their diets.

Benthic Fish Consumers (N=66)	**Meals Eaten Each Month**		
	Population Percentiles		
	50th	**95th**	**99th**
Other Fish Consumption Rates	1.0	4.4	8.5
Water Body Specific Fish Consumption Rates	2.0	10	20
Combined Fish Consumption Rates	3.0	11	26

Table 5. Meals per month of fish consumption for Saginaw Bay Watershed fish consumers (number of consumers) that include catfish in their diets.

Catfish Consumers (N=50)	Meals Eaten Each Month		
	Population Percentiles		
	50th	95th	99th
Other Fish Consumption Rates	1.0	4.0	9.9
Water Body Specific Fish Consumption Rates	2.0	8.9	15
Combined Fish Consumption Rates	3.0	9.6	23

Table 6. Meals per month of fish consumption for Saginaw Bay Watershed fish consumers (number of consumers) that include carp in their diets.

Carp Consumers (N=9)	Meals Eaten Each Month		
	Population Percentiles		
	50th	95th	99th
Other Fish Consumption Rates	1.0	4.6	4.9
Water Body Specific Fish Consumption Rates	2.0	3.4	3.9
Combined Fish Consumption Rates	2.5	5.3	5.5

Appendix 5 Calculation of DLC meal concentrations for the Saginaw River fish consumption scenarios.

The DLC concentrations used to represent the fish meals in the Saginaw River fish consumption scenarios were estimated based on the average measured concentrations in walleye, yellow perch, white bass, trout, carp and catfish from either the Saginaw River or Bay. One exception was walleye that also included DLC results from Tittabawassee River walleye. Walleye are known to migrate from Saginaw Bay into the Tittabawassee River.

The five fish consumption scenarios are described in the *Toxicological Evaluation* section of this report. The Catfish Only, Walleye Only, Carp Only consumption scenarios were assigned the average DLC concentrations for each given species as reported in Appendix 3. The *Mixed Sport Fish* calculation is an equal weighting of the average concentration of the open water species reported in the table below. The *Mixed Benthic* calculation is an equal weighting of the average concentration of all species (both benthic and open water) reported in the table below. For fillets from species that have not been analyzed for DLC from the water system, an average tissue concentration was assigned from a fish species of generally similar life history characteristics. For example, crappie was assigned the measured DLC for walleye fillets, and suckers and freshwater drum were assigned the measured DLC for catfish fillets.

Type	**Species**	**Mean ppt-TEQ$_{d,f,p\ WHO\ 2005}$**
Sport fish	Walleye	2.6[a]
Sport fish	Perch	0.71[a]
Sport fish	Smallmouth Bass	17[b]
Sport fish	Largemouth Bass	17[b]
Sport fish	White Bass	17[a]
Sport fish	Bluegill	0.71[b]
Sport fish	Crappie	2.6[b]
Sport fish	Northern Pike	17[b]
Sport fish	Trout	13[a]
Benthic	Catfish	16[a]
Benthic	Carp	420[a]
Benthic	Suckers	16[b]
Benthic	Freshwater Drum	16[b]
	Mixed Benthic Fish[c]	**43**
	Mixed Sport Fish[d]	**10**
	Catfish Only	**16**
	Walleye Only	**2.6**
	Carp Only	**420**

[a] Mean measured fish tissue concentrations by MDEQ as reported in Appendix 3, Table 2.
[b] These are not measured concentrations. MDCH assigned these concentrations based on similar behaviors.
[c] Average of all fish listed both sport and benthic fish.
[d] Average of all sport fish listed.

Appendix 6 Equations and parameters for DLC intake estimates for Saginaw River fish consumption scenarios.

Parameter	Parameter Selection (units)	Description
Intake Equation	$Intake = \left(\left(\frac{C \times Ir \times Ed}{Bw \times At} \right) \times Abs \right) + Bck$	Intake Equation resulting in daily (pg/kg/d) estimates
(C) Concentration in Diet	Table 6 (pg TEQ/g)	Average DLC TEQ concentration in the Saginaw River fish fillets.
(Ir) Ingestion Rate	Table 6 (g/day)	Amount of daily fish consumption for average or frequent fish consumers in each exposure scenario.
(Bw) Body Weight	Table 6 (kg)	Average body weights were assigned to scenarios on the basis of age.
(Abs) Absorption into bloodstream	Absorption food = 100% (unitless) Absorption dust/soil = 50% (unitless)	MDCH used 100% absorption for food ingested TEQ (Schlummer et al. 1998, Harrad et al. 2003, Moser et al. 2001). MDCH used the 50% for soil.
(Bck) Background DLC exposure includes purchased fish consumption	Appendix 8 (pg TEQ/kg/d)	MDCH estimated background daily DLC exposure according to Appendix 8.
Cooking and Trimming Reduction	Not included in the equation	No reduction to fish tissue concentrations is being applied to the calculations because MDCH cannot assume that everyone will trim and cook their fish properly.
<u>NONCANCER ASSUMPTIONS</u>		
(Ed) Exposure Duration	Chronic	DLC accumulate in human tissues over a lifetime, thus exposures are chronic.
(At) Averaging Time	Equal to exposure duration (days)	Exposures are annualized and calculated on a grams-of chemical-per-day basis.
<u>CANCER ASSUMPTIONS</u>		
Exposure Duration	30 years	Upper bound of living at a single residence.
Averaging Time	70 years	Average length of life.

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Appendix 7 Equations and parameters for DLC cancer and non-cancer estimates for Saginaw River fish consumption scenarios.

Assessment	Equation	**Description**
Non-cancer	Hazard Quotient Equation HQ = TEQ Intake / Comparison Value	Comparison value is 1 pg/kg/day. HQ values greater than 1 show that intake values exceed comparison values.
Cancer	Cancer Risk Equation Risk = (TEQ Intake * CSF) *100,000 Where, Risk = upper bound estimate of the incremental lifetime cancer number per 100,000 exposed individuals. TEQ intake = pg/kg/d, calculated in accordance with Appendix 5. CSF = Cancer Slope Factor of 0.000075 $(pg/kg/d)^{-1}$	Cancer Potency Factor is an estimate of the potency of DLC with regards to causing cancer. The risk calculation is presented in context of the number of additional cancers per 100,000 exposed persons.

Appendix 8 Information to calculate national background estimates of DLC exposure.

MDCH developed average national background dioxin estimates by inserting the values in Tables A, B, C, and D into the equations presented in Table E. The references for each value are provided. Where possible, the dioxin concentrations use zero for non-detections, which is the same method used in the Michigan fish consumption advisory. Food concentrations are calculated from the US FDA's most recent (2004) dioxin and furan dataset. Background concentrations are calculated using WHO 1998 method (Van den Berg et al. 1998). A more recent method by the WHO (Van den Berg et al. 2005) is now available. Given that the raw data necessary to implement the WHO 2005 methods was not provided, the data in Table A may overestimate the dioxin and furan concentrations by approximately 25% (Wittsiepe et al. 2007). However, these background numbers do not include PCB DLCs, which would underestimate the DLC food concentrations. Schecter et al. (1997, 2001) reported that, on average, PCB DLCs contribute approximately 28-33% of the total DLC content in US food. These factors are likely to offset one another.

Table A. Estimates of dioxin concentrations for air, food, soil, and water.[a]

No.	Media	Concentration	Units	References
1	Air	0.012	pg/m^3	Cleverly et al. 2000
2	Beef	0.195	ppt TEQ whole weight	US FDA 2004[b]
3	Dairy	0.083	ppt TEQ whole weight	US FDA 2004[b]
4	Eggs	0.016	ppt TEQ whole weight	US FDA 2004[b]
5	Purchased Fish	0.062	ppt TEQ whole weight	US FDA 2004[b]
7	Milk	0.004	ppt TEQ whole weight	US FDA 2004[b]
8	Pork	0.007	ppt TEQ whole weight	US FDA 2004[b]
9	Poultry	0.003	ppt TEQ whole weight	US FDA 2004[b]
10	Soil	6	ppt TEQ dry weight	MDEQ 2004
11	Vegetable Fat	0.008	ppt TEQ whole weight	US FDA 2004[b]
12	Water	0.00056[c]	ppq	Jobb et al. 1990

[a] Estimates include chlorinated dibenzo-*p*-dioxins and chlorinated dibenzofurans but do not include PCBs.
[b] US FDA food estimates are based on WHO 1998 TEF and non-detections are reported as zero.
[c] Non-detections are reported as zero.

MDCH used the rates of ingestion and inhalation for a child and an adult scenario listed in Table B. MDCH based the purchased fish intake estimates on reported meals per month from Saginaw Bay Watershed fishers for fish consumption from other sources than the water body being fished at the time of the interviews (MDCH 2007) (Table D). MDCH set the meal size for adults to equal 227 g (8 ounces) and for children to equal 113 g (4 ounces). MDCH established the purchased fish consumption estimates to be similar to the fish consumption scenarios described in Appendix 4. MDCH set the average fish consumption intake at the 50th percentile and the frequent fish consumption intake at the 95th percentile. The selection of the fish consumption scenarios is described in the *Toxicological Evaluation* section.

Table B. Ingestion or inhalation rates by media.

No.	Media	Units	Child	Adult	References
1	Air (inhalation)	m^3/d	13.5[c]	13.3[e]	U.S. EPA, 1997b
2	Beef	g/d	63	83	See Table C, Below
3	Dairy	g/d	47	56	See Table C, Below
4	Eggs	g/d	16	26	See Table C, Below
5	Fish – Purchased[a]	g/d			See Table D Below
6	Milk	g/d	398	248	See Table C, Below
7	Pork	g/d	18	27	See Table C, Below
8	Poultry	g/d	25	45	See Table C, Below
9	Soil Ingestion[b]	g/d	0.1	0.05	U.S. EPA, 1997a
10	Vegetable Fat[e]	g/d	7.37	7.4	U.S. EPA, 1997b
11	Water ingestion	L/d	0.74[d]	1.4[f]	U.S. EPA, 1997a

[a] See Table D below.
[b] U.S. EPA 1997a, Table 4-23.
[c] U.S. EPA 1997a, Table 5-23, mean value for 9- to 11-year-olds for males and females combined.
[d] U.S. EPA 1997a, Table 3-30, mean value for 1- to 10-year-olds.
[e] Average of U.S. EPA 1997a, Table 5-23, *Adults-Female* and U.S. EPA 1997a, Table 5-23, *Adults–Male*.
[f] U.S. EPA 1997a, Table 3-30, *Adults.*

Table C. Calculation of consumption rate estimates, by food type.

Food Type	**Scenario**	**Individual Estimates**						**Mean**
		g/d	**g/d**	**g/d**	**g/d**	**g/d**	**g/d**	**g/d**
Eggs	Child 6–12 yrs old	17[a]	17[b]	14[b]				16
	Female	17[b]	23.5[c]	26.9[a]	37.8[d]	27[e]	20[b]	**25**
	Male	23.5[c]	26.9[a]	37.8[d]	27[e]	27[b]	20[b]	**27**
Milk	Child 6–12 yrs old	446[a]	439[b]	310[b]				**398**
	Female	279.7[c]	253.5[a]	289.7[d]	266[e]	148[b]	224[b]	**243**
	Male	279.7[c]	253.5[a]	289.7[d]	266[a]	202[b]	224[b]	**252**
Beef	Child 6–12 yrs old	63.4[a]						**63**
	Female	55.9[f]	92.9[c]	87.6[a]	78.4[g]			**79**
	Male	92.9[c]	86.8[f]	87.6[a]	78.4[g]			**86**
Pork	Child 6–12 yrs old	18.2[a]						**18**
	Female	18.8[f]	29.6[c]	28.2[a]				**26**
	Male	26.5[f]	29.6[c]	28.2[a]				**28**
Poultry	Child 6–12 yrs old	24.7[a]						**25**
	Female	26.6[c]	44.7[f]	31.3[a]	72.1[g]			**44**
	Male	26.6[c]	51.7[f]	31.3[a]	72.1[g]			**45**
Other Dairy	Child 6–12 yrs old	47.3[a]						**47**
	Female	56.5[c]	55.1[a]					**56**
	Male	56.5[c]	55.1[a]					**56**

[a] U.S. EPA 1997b, Table 11-16.
[b] U.S. EPA 1997b, Table 11-13.
[c] U.S. EPA 1997b, Table 11-17.
[d] U.S. EPA 1997b, Table 11-20.
[e] U.S. EPA 1997b, Table 11-12.
[f] U.S. EPA 1997b, Table 11-21.
[g] U.S. EPA 1997b, Table 11-19.

Table D. Average (50th percentile) and frequent (95th percentile) purchased fish consumption intakes for adult and child Saginaw Bay Watershed fish consumption scenarios. [a]

Titles of Fish Consumption Scenarios	Average 50th percentile		Frequent 95th percentile	
	meals/month	**grams/day**	**meals/month**	**grams/day**
ADULTS				
Walleye Only	1	7.6	3	22.7
Catfish Only	1	7.6	3	22.7
Carp Only	1.25	9.4	3	22.7
Mixed Open Water	1	7.6	3	22.7
Mixed Benthic	1	7.6	3.5	26.5
CHILD				
Walleye Only	1	3.8	3	11.3
Catfish Only	1	3.8	3	11.3
Carp Only	1.25	4.7	3	11.3
Mixed Open Water	1	3.8	3	11.3
Mixed Benthic	1	3.8	3.5	13.2

[a] Meals per month are based on the MDCH 2007 report in which local fishers are asked to estimate consumption of other sources of fish away from the water body the respondent was fishing at the time of the interview. The grams per day is based on an 8-ounce meal size and the meal frequency average over the number of days in a year.

Table E. Parameters and equation for background dioxin intake calculations.

Parameter in Equation	Parameter Selection (units)	Description
Background Intake	$\sum_{i=1}^{11} X_i$, Where X is the intake equation for each dioxin source, i listed in Table A.	Summation of the background intake estimates.
Intake Equation	$X = \left(\frac{C \times Ir \times Ed \times Abs}{Bw \times At} \right)$	Intake Equation resulting in daily (pg/kg/d) exposure.
(C) TEQ Concentration in Diet	Table A (see table for units)	Estimates of TEQ concentration in media (air, water, food, soil).
(Ir) Ingestion Rate	Table B and D (see table for units)	Ingestion/contact rates for each media by human exposure scenario.
(Bw) Body Weight	Adults = 70 kg; Child = 28 kg	Average body weights were assigned to scenarios based on age.
(Abs) Absorption into blood stream	Absorption food = 100% (unitless) Absorption dust/soil = 50% (unitless)	MDCH used 100% absorption for food ingested TEQ (Schlummer et al. 1998, Harrad et al. 2003, Moser et al. 2001). MDCH used 50% for absorption from soil.
	<u>NONCANCER ASSUMPTIONS</u>	
(Ed) Exposure Duration	Lifetime (days)	Background exposures are occurring throughout life. Breast-feeding is not included in these estimates because Lorber and Phillips (2002) estimate that dioxin exposure is initially high but returns to background levels by age 5.
(At) Averaging Time	Equal to exposure duration (days)	Exposures are annualized and calculated on a gram of chemical per day basis.

<u>CANCER ASSUMPTIONS</u>

Cancer rates are not calculated for background concentrations because upper-bound cancer risk estimates represent the theoretical incremental individual increase in cancer above the background cancer risk. Thus background intake rates are not included in the cancer estimates.

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Appendix 9 Evaluation of uncertainty related to DLC cancer potency factors.

Several state and federal government agencies have proposed DLC cancer potency factors based on linear extrapolation methods that vary from 26,300 $(mg/kg\text{-}day)^{-1}$ to 1,000,000 $(mg/kg\text{-}day)^{-1}$ (Faust and Zeise 2004, US EPA 2000, US EPA 1997) (Table 1). Michigan uses a cancer potency factor of 75,000 $(mg/kg\text{-}day)^{-1}$. These cancer potency factors are either based on toxicology studies of animal models (NTP 2004, Kociba et al. 1978) or epidemiologic studies of human exposures (US EPA 2000). Although these cancer potency factors differ by a factor of 38 from the lowest to the highest value, the cancer risk estimates are still above Michigan's level of concern (1 additional cancer per 100,000 individuals exposed), and thus MDCH's finding's of a *public health hazard* for most Saginaw River fish consumption patterns would not change regardless of the CSF in Table 1 used (Table 2). In most cases the incremental lifetime individual cancer risk (upper bound) estimates increased reaching a potential maximum risk of 1 additional cancer per 25 exposed individuals (3,900 additional cancers per 100,000 people eating 2 (227 gram) meals of carp per month).

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Table 1. Cancer potency factors used or proposed by state or federal agencies.

Cancer Potency Factors (mg/kg-day)$^{-1}$	Data Sets	Reference
26,300	Rat model NTP 2004 - allometric scaling to humans	Faust and Zeise 2004
75,000	Rat model Kociba 1978 - allometric scaling to humans	Michigan DEQ
150,000	Rat model Kociba 1978 - allometric scaling to humans	US EPA 1997
391,000	Rat model NTP 2004 - body burden scaling to humans	Faust and Zeise 2004
1,000,000	Human epidemiologic data	U.S. EPA 2004

Table 2. Range of excess incremental lifetime cancer risk when applying the cancer potency factors from appendix 8, table 1 to the Saginaw River fish consumption scenarios.

	Incremental Lifetime Individual Cancer Risk (upper bound) (x10^{-5})									
	Cancer Potency Factors (mg/kg-day)$^{-1}$									
Fish Consumption	*75,000*		*26,300*		*150,000*		*391,000*		*1,000,000*	
Scenario	Average	Frequent	Average	Frequent	Average	Frequent	Average	Frequent	Average	Frequent
Walleye Only	1.8	4.5	0.6	1.6	3.6	9.0	9.4	23	24	60
Catfish Only	10	36	3.5	13	20	72	52	190	130	480
Carp Only	180	290	63	100	360	580	940	1,500	2,400	3,900
Mixed Open Water	6.9	27	2.4	9.5	14	54	36	140	92	360
Mixed Benthic	29	110	10	39	58	220	150	570	390	1,500