Health Consultation

Tittabawassee River Fish Consumption Health Consultation

TITTABAWASSEE RIVER
MIDLAND, MIDLAND COUNTY, MICHIGAN

EPA FACILTIY ID: MID980994354

JULY 27, 2005

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

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An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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EPA FACILTIY ID: MID980994354

Prepared by:

Michigan Department of Community Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

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Abbreviations and Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
DLC	Dioxin-like compound
EPA	U.S. Environmental Protection Agency
kg	Kilograms
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDNA	Michigan Department of Natural Resources
MIX	mixed diet of walleye, sport fish, and benthic fish
NTP	National Toxicology Program
PCBs	Polychlorinated biphenyls
pg	picograms
ppt	parts per trillion
TCDD	Tetrachlorodibenzo-*p*-dioxin
TEF	Toxic equivalency factor
TEQ	Toxic equivalency
WHO	World Health Organization

Summary

The Agency for Toxic Substances and Disease Registry and Michigan Department of Community Health received a petition about the dioxin contamination along the Tittabawassee River downstream of the city of Midland. Elevated concentrations of dioxin and dioxin-like chemicals have been found in Tittabawassee River fish. People eating Tittabawassee River fish ingest dioxin and dioxin-like chemicals in amounts greater than those of the average U.S. resident. Past and current dioxin and dioxin-like chemical exposures from the consumption of certain diets of Tittabawassee River fish were and are a *public health hazard.* Future exposure to dioxin and dioxin-like compounds from ingestion of Tittabawassee River fish is an *indeterminate public health hazard.*

Purpose and Statement of Health Issues

Purpose

The purpose of this health consultation is to assess the health risks associated with dioxin exposure from both average and frequent ingestion of Tittabawassee River fish.

Petitioned Health Consultation

This health consultation was conducted in response to a petition filed in 2001 with the Agency for Toxic Substances and Disease Registry (ATSDR) (Appendix 1). This petition refers to dioxin as the contaminant of concern and states, “the primary source of this contamination (dioxin) is the Dow Chemical Company.” Petitioners specifically mention the chronically elevated concentrations of dioxin found in Tittabawassee River fish.

Basis for Public Health Concern

Dioxins are a group of 210 chlorinated chemicals with similar structures and chemical properties (Figure 1). This group of chemicals, which includes chlorinated dioxins, furans, and some polychlorinated biphenyls, often is collectively referred to as “dioxins” or “dioxin-like compounds” (DLCs).

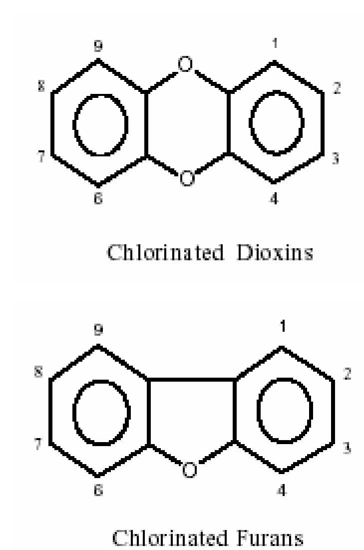

Figure 1 Generalized structure of dioxin and furan chemicals.

The most toxic chemical in the group is 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). Toxic equivalency factors (TEF) have been developed to compare the relative toxicity of DLCs to that of 2,3,7,8-TCDD. The levels of other DLCs measured in the environment are multiplied by TEFs to produce a 2,3,7,8-TCDD toxic equivalent or TEQ concentration. The resulting TEQs for DLCs measured in a sample are then totaled to determine the total TEQ concentration for that sample.

DLCs are not intentionally produced and have no known use. In the environment, DLCs are usually a mixture of these chemicals. Once in the environment, DLCs degrade slowly and persist in soils and organisms for a long time. DLCs accumulate in sediment and organisms. Fish living in contaminated water bodies can accumulate significant amounts of DLCs.

The Michigan Department of Environmental Quality (MDEQ) reported soils and sediments within the Tittabawassee River and associated flood plain have elevated concentrations of DLCs greater than State of Michigan cleanup criteria (MDEQ 2003). DLCs in the soils and sediments appear also to have entered the human food chain, as indicated by elevated dioxin concentrations in local domesticated animals (i.e., chicken eggs from free-range chickens feeding on the Tittabawassee River flood plain) (MDEQ 2003), wild game (i.e., turkeys, deer, and squirrels) (Entrix 2004), and Tittabawassee River fish (MDCH 2003). MDCH has issued "no-consumption" advisories on several species of fish from the Tittabawassee River, and wild game on and around the flood plain.

According to the Michigan United Conservation Club Web site (http://www.mucc.org/inside/districts/district10.html), approximately 30 sport hunting and fishing clubs exist in the five counties surrounding the Tittabawassee River. An article entitled *Combos best for Tittabawassee walleye*, on the Web site *ESPN Outdoors* (http://espn.go.com/outdoors/fishing/s/f_map_MI_Tittabawassee_River.html) reports on the great fishing opportunities on the Tittabawassee River. Hunting and fishing are common activities in this region of Michigan (Appendix 2) making periodic exposures to DLCs possible. Understanding the potential health implications of these exposures is necessary for people to make informed choices about eating fish.

Background

The Dow Chemical Company was incorporated in 1897 in Midland, Michigan. Initially, the company extracted chlorides and bromides from brine deposits under Midland and produced bromine and bleach. Today Dow Chemical is one of the largest chemical companies in the world. It produces a wide range of chemicals used in plastics, pesticides, and other products. For example, Dow has produced chemicals such as styrene, urethane, terphthalate, and propylene for plastics and chlorpyrifos for pesticides (trade name: Lorsban or Dursban).

Historically, waste generated from this process was stored on-site in 600 acres of human-made ponds. During high-flow events in the early 1900s, waste from ponds was intentionally released into the Tittabawassee River (Brandt 1997). Currently, Dow operates on-site wastewater treatment facilities. In 1986, a flood in the Tittabawassee River and surrounding region overwhelmed the Dow wastewater treatment plant in

Midland and areas of the property where soils were contaminated with DLCs. The containment systems and dikes, intended to prevent release of untreated or partially treated chemical waste, overflowed and entered the Tittabawassee River (Wilkerson 1986, Schmidt 1986). In addition, the Tittabawassee River frequently overflows its banks as a result of melting snow coupled with heavy spring rains. The presence of DLC contamination 3–4 feet below the ground surface in some areas along the river indicates the contamination has been accumulating over an extended period (MDEQ 2003).

Discussion

Environmental Data

Tittabawassee River fish fillet DLC data for multiple species and years were compiled from various sources and are discussed in Appendix 3. The State of Michigan uses fish fillet data to provide fish consumption advice for people fishing the Tittabawassee River. The 1992–2003 data also are used in this consultation to conduct exposure, noncancer, and cancer evaluations (Table 1). MDCH laboratory staff reviewed and verified the sample data. MDCH reported the fish fillet concentrations in units of picograms (pg) TEQ per gram of edible (e.g., wet weight) fish tissue (parts per trillion [ppt]-TEQ). Of the species analyzed, walleye had the lowest concentrations, ranging from 1.2-5.7 ppt-TEQ. Concentrations in smallmouth bass, white bass, and carp were 3.1–15 ppt-TEQ, 4.6–24 ppt-TEQ, and 3.0–373 ppt-TEQ, respectively.

Table 1. Mean, minimum, and maximum DLC fillet concentrations from five species of Tittabawassee River fish

Species	Year	Tissue Type	Number of Samples	Fish Length Range (cm)	Mean	Min	Max
					ppt-TEQ		
Carp	1992, 1999, 2003	skin-off fillet	21	42.0–75.0	47.3	3.0	373
Catfish	2003	skin-off fillet	10	42.8–63.4	12.1	3.9	31
Smallmouth Bass	1999, 2000, 2003	skin-on fillet	25	33.7–46.5	8.43	3.1	15
Walleye	1992, 2000, 2003	skin-on fillet	22	36.7–54.6	3.02	1.2	5.7
White Bass	1995, 2003	skin-on fillet	20	25.0–39.5	13.6	4.6	24

Exposure Pathways

For a health risk to exist from DLCs, the chemicals must enter a person's body either through inhalation, ingestion, or dermal contact. Most DLC exposures result from ingestion, followed by absorption into the body through the gastrointestinal track. Fish, when coming from DCL-contaminated water bodies, can be a food source that is high in DLCs.

The Tittabawassee River has sediments and fish contaminated with DLCs. Fish harvesting and ingestion from the Tittabawassee River are extensive; walleye is the most commonly harvested fish. In 1988, a report documented that more than half the people fishing the Tittabawassee River either ate the fish they caught or gave it to friends (Smith and Enger 1988). The Michigan Department of Natural Resources (MDNR), in an effort to track walleye harvest from the river, conducts a yearly creel census during January through May. From 1999 to 2002, MDNR creel census documented an average harvest over 5 months of 16,276 fish comprising 14 different fish species being taken home by anglers and 66,357 hours spent fishing by anglers (MDNR 2004).

An exposure pathway contains five elements: (1) a source of contamination, (2) contaminant transport through an environmental medium, (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 exists if at least one element is missing and will never be present.

Exposures to DLCs from consumption of Tittabawassee River fish are occurring and have occurred (Table 2). Future DLC exposure will be determined partly by future concentrations in the fish. DLC fish data were not sufficient to conduct a rigorous temporal trend analysis to determine future concentrations. A non-rigorous comparison between 1992 and 2003 within each species that had multiple years of data did not show any apparent increasing or decreasing DLC trends. Therefore, the potential exists for continued DLC exposures to people eating fish from the Tittabawassee River well into the future.

Table 2. Pathway of human exposure to DLCs from fish in the Tittabawassee River

Source	**Chemical**	**Transport**	**Exposure**			**Time Frame**	**Status**
			Point	**Route**	**Population**		
Historic release to surface water	DLCs	Water and sediment	Fish from the Tittabawassee River	Ingestion	Fish consumers	Past	Complete
						Present	Complete
						Future	Potential

<u>Estimates of Background DLC Exposures Not Related to the Tittabawassee River</u>
DLCs are found at low levels of contamination in many U.S. store-purchased foods, such as beef, milk, fish, and cheese. Therefore, exposure to these chemicals is unavoidable, and everyone in the United States is exposed to some amount of DLCs every day.

For three human scenarios (Table 3), MDCH estimated average national background DLC intake rates from dermal contact and ingestion of contaminated food, water, air, and soil (Table 4). These background rates are meant to represent DLC exposure in the United States outside of a locally contaminated area such as the Tittabawassee flood plain. These background exposure estimates are based on U.S. national consumption patterns and either Michigan-specific, regional (Midwest), or national DLC concentrations in food, air, water, and soil (Appendix 4).

Table 3. Human scenarios for a child, adult female, and adult male who are average and frequent fish consumers, by fish consumption meal sizes, daily consumption rates in grams per day (g/d), and meals per month

Scenario	Age Group	Body Weight	Meal Size	Average Consumption Rate	Number of Meals per Month	Frequent Consumption Rate	Number of Meals per Month
	Years	**kg**	**Ounces**	**g/d**		**g/d**	
Child	8	28	4.4	4.08	1	20.1	5
Adult Female	30	64	7.4	6.93	1	38.0	5
Adult Male	30	79	9.7	9.05	1	66.4	7

Table 4. Average national background DLC exposure estimates for three human exposure scenarios of consuming an average or frequent amount of fish that does not include Tittabawassee River fish

	Average			Frequent		
Daily and Monthly TEQ Intake Rates	**Child**	**Female**	**Male**	**Child**	**Female**	**Male**
pg/kg/day						
Background with Freshwater Fish Consumption	0.98	0.51	0.44	1.51	0.95	1.08
Background without Freshwater Fish Consumption	0.87	0.43	0.36	0.98	0.51	0.46
pg/kg/month						
Background with Freshwater Fish Consumption	29.8	15.4	13.5	46.0	28.8	32.9
Background without Freshwater Fish Consumption	26.6	13.0	11.0	29.8	15.4	13.9

Estimates of Added DLC Exposure from Eating Tittabawassee River Fish

To evaluate risk to consumers from Tittabawassee River fish, MDCH estimated the DLC intake of average and frequent freshwater fish consumers for three scenarios (Table 3). These fish consumption rates were based on a 2002 U.S. Environmental Protection Agency (EPA) national fish consumption report. The EPA report estimated freshwater and marine fish ingestion for males and females of various ages (EPA 2002). MDCH estimated that the average fish consumer may eat one meal of Tittabawassee River fish per month. MDCH estimated that frequent fish consumers may eat 5–7 meals of Tittabawassee River fish per month (Table 3). The average and frequent fish consumption rates are the 90% upper bound confidence limit on the mean and 95th percentile, respectively (upper bound values make it unlikely that the average and frequent freshwater fish consumers will exceed these values).

MDCH grouped fish species as the most commonly eaten fish (walleye), those feeding away from the river bottom (other sport fish), and those feeding from the river bottom (benthic feeders) (Table 5). MDCH designated each group of fish as a Tittabawassee fish diet (Diet A: Walleye; Diet B: Other Sport Fish; Diet C: Benthic Feeders) and calculated an average tissue concentration for each diet. MDCH used a percentage of the DLC concentration from each Tittabawassee fish diet (A, B, & C), with percentages derived from estimates from Smith and Enger (1988), to estimate a dioxin concentration for a mixed diet (MIX) of walleye, sport fish, and benthic fish.

Table 5. Descriptions and concentrations of DLCs in four human diets of Tittabawassee River fish

Name of Tittabawassee Fish Diet	Species in Diet	Percentage of Fish in MIX Diet	Mean Fillet Concentration by Diet pg-TEQ/g fish
A Walleye	Walleye	39%	3.0
B Other Sport Fish	Smallmouth Bass, White Bass, Northern Pike, Pan Fish	35%	11
C Benthic Feeders	Carp, Catfish, Suckers, Bullheads	26%	30
MIX	Mixture of above list	n/a	13

MDCH combined the DLC concentrations in each diet (Table 5) with the scenario-specific fish consumption rates for average and frequent fish consumers (Table 3) and the average national background DLC exposure estimates (Table 4) to calculate the rate of DLC intake from ingestion of Tittabawassee River fish, which includes background DLC intake (Table 6; Appendix 5).

Table 6. Daily (pg/kg/day) and monthly (pg/kg/month) estimates of DLC intake for average and frequent consumers of Tittabawassee River fish, by diet including background DLC intake.

Diet	Average Fish Tissue Pg TEQ/g	Daily (pg-TEQ/kg/d)						Monthly (pg-TEQ/kg/m)					
		Average			Frequent			Average			Frequent		
		Child	Female	Male	Child	Female	Male	Child	Female	Male	Child	Female	Male
Back-ground[a]	0.74	1.0	0.5	0.4	1.5	1.0	1.1	30	15	14	46	29	33
A[b]	3.0	1.3	0.8	0.7	3.1	2.3	3.0	40	23	21	95	70	91
B[b]	11	2.5	1.6	1.6	8.9	7.1	9.7	75	49	49	270	210	300
C[b]	30	5.2	3.7	3.8	23	18	26	160	110	120	690	560	780
MIX[b]	13	2.8	1.8	1.8	10	8.2	11	84	56	56	310	250	350

[a] Background DLC exposure estimates that include freshwater fish not from the Tittabawassee River.
[b] Tittabawassee River fish diets.

Cancer Health Assessment

MDCH estimated the excess incremental lifetime cancer risk level to people who eat Tittabawassee River fish (Table 7). These estimates are not reported cancers in the community but mathematically generated values based on the best available data and commonly used risk assessment methods. All such cancer risk assessment estimates are considered theoretical. These estimates are based on the DLC intake rates presented in Table 6. In general, MDCH considers risk levels exceeding one additional cancer per 100,000 exposed people (1 x 10^{-5}) to require MDCH intervention, except when background exposure estimates also exceed this risk level. In situations where background exposures exceed this risk level, MDCH considers a cancer risk level above background to require MDCH intervention. Excess incremental lifetime cancer risk level estimates are meant to protect sensitive persons; thus, most people who eat Tittabawassee River fish face less risk than suggested by the estimates, and for some people the risk may even be zero. The equations used to calculate these estimates are presented in Appendix 6.

MDCH estimated that cancer risk level associated with nationwide, unavoidable DLC exposure (i.e., background exposure) exceeded one additional cancer per 100,000 exposed persons (Table 7). MDCH displayed the cancer risk level above background by subtracting the background cancer risk level from the matching Tittabawssee River fish diets (A, B, C, and MIX) (Figures 2 and 3). For example, for an average female eating fish diet B, MDCH did the following: cancer risk level of diet "B" (7) minus background cancer risk level (4) equals the cancer risk level above background (3) (i.e., 7 – 4 = 3).

Table 7. Estimated cancer risk levels, per 100,000 persons, associated with exposure to national background DLC contamination and DCL exposure from eating fish from the Titttabawassee River (minimal risk level is 1 in 100,000)

Population	Cancer Risk Level (x 10^{-5}) Associated with Background DLC Exposures[a]	DLC Exposure from Tittabawassee River Fish Diets[b]			
		A	B	C	MIX
Adult Female					
Average Fish Consumption	4	4	7	13	8
Frequent Fish Consumption	7	9	24	60	28
Adult Male					
Average Fish Consumption	3	4	7	14	7
Frequent Fish Consumption	8	12	33	84	39

[a] Background DLC exposures include freshwater fish consumption with an assumed average contamination level for freshwater fish tissue of 0.74 ppt-TEQ (Fish not from the Tittabawassee River).
[b] Tittabawassee River fish diets include background DLC exposures; however, the freshwater fish consumption component is replaced with the consumption of Tittabawassee River fish.

For a female population, average Tittabawassee River fish consumers may face increased cancer risk levels of 0 to 9 x 10^{-5} above background over a lifetime (Figure 2). Frequent cnsumers of Tittabawassee River fish may face increased cancer risk levels of 2 to 53 x 10^{-5} over a lifetime above background (Figure 2).

For a male population, average Tittabawassee River fish consumers may face increased cancer risk levels of 1 to 11 x 10^{-5} above background over a lifetime (Figure 3). Frequent consumers of Tittabawassee River fish may face increased cancer risk levels of 4 to 76 x 10^{-5} above background over a lifetime (Figure 3).

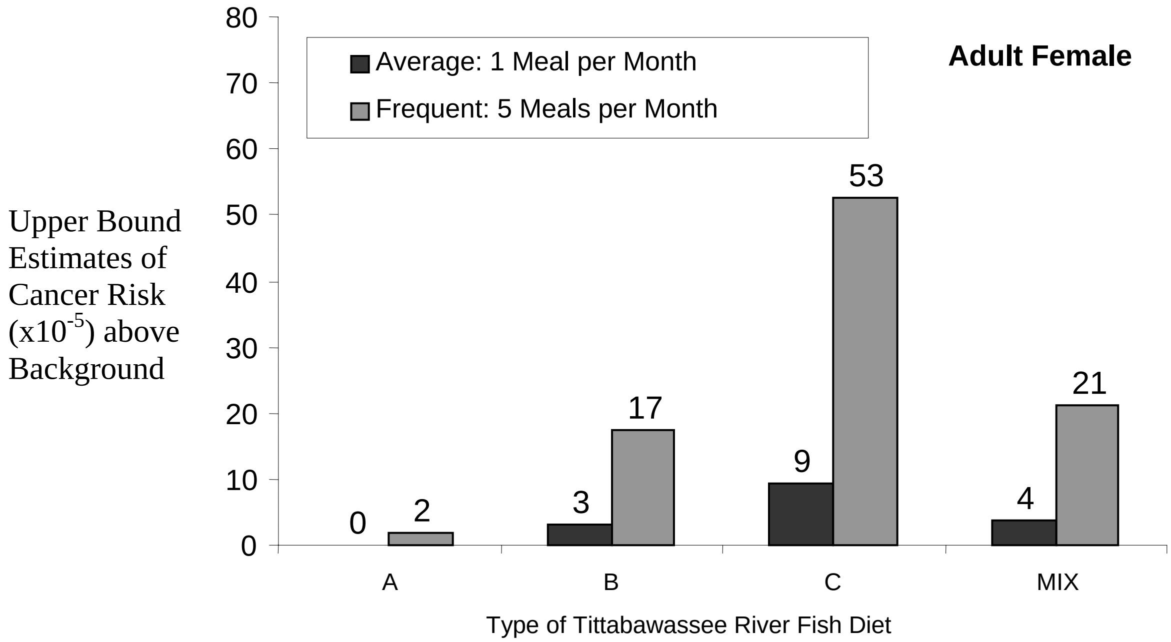

Figure 2. Upper bound estimate of cancer risk ($x10^{-5}$) above background that a female population of average and frequent Tittabawassee River fish consumers may experience over a lifetime.

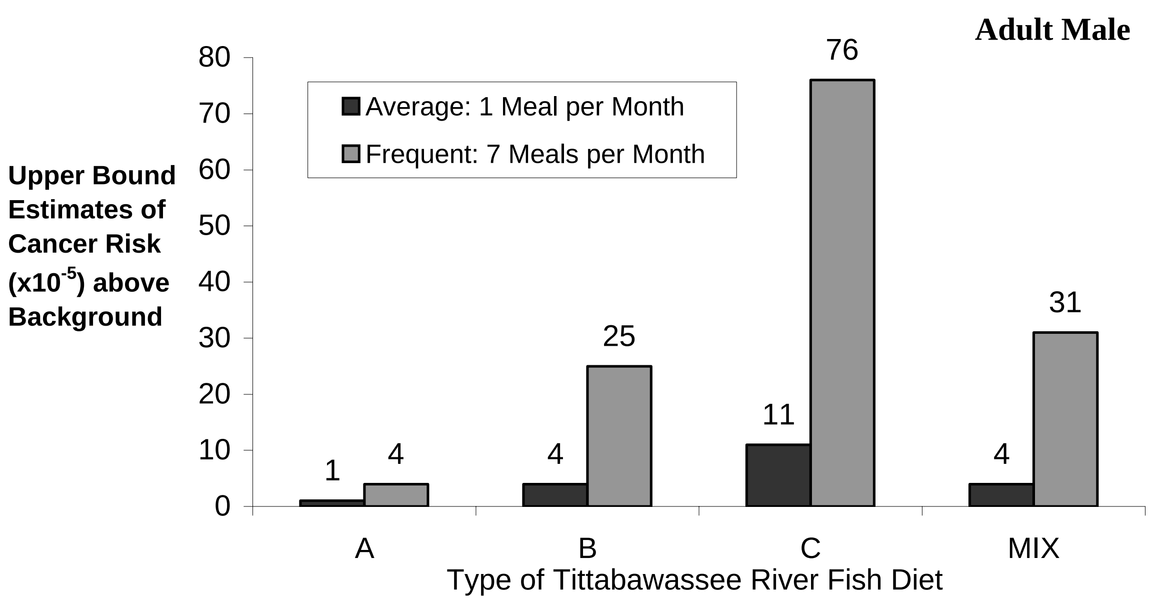

Figure 3. Upper bound estimate of cancer risk ($x10^{-5}$) above background that a male population of average and frequent Tittabawassee River fish consumers may experience over a lifetime.

Noncancer Health Assessment

Several governmental sources have released chronic dioxin intake comparison values, below which repeated exposures to DLCs are unlikely to be associated with appreciable risk for adverse effects (noncancer) (Table 8). Comparison values are meant to protect all people—including those who are most sensitive—and if a person's exposure is below these comparison values, then his or her risk would be expected to be minimal if not zero. Automatically assuming that exceeding these values would produce adverse effects is not correct. Rather, exceeding these values would mean a person is above a level that can be called minimal risk, and further evaluation of the exposure is necessary to characterize the impact of such an exposure situation.

If a person swallows food or water containing DLCs, most of the DLCs will enter the body and pass from the intestines to the bloodstream. Once there, DLCs can be found in most tissues, with the highest amounts in the liver and body fat (adipose tissue). Body fat and possibly the liver can store DLCs for many years before eliminating them from the body.

Human studies involving DLCs have shortcomings, making association between 2,3,7,8-TCDD exposure levels and health effects difficult to establish scientifically. A common problem with most of the human studies is that people are exposed to a number of chemicals at the same time. In most human health studies, we do not know to how much 2,3,7,8-TCDD people were exposed or for how long the exposure lasted. In other studies, people were examined many years after exposure, and some of the effects may not have been present at the time of examination or the effects observed may not have been caused by 2,3,7,8-TCDD.

Table 8 Noncancer governmental comparison values for DLCs.

Agency	Daily Intake Comparison Values pg TEQ/kg/day	Monthly Intake Comparison Values pg TEQ/kg/month
ATSDR	1	30
WHO	1	30
GLWQI[a]	1.3	40
WHO[b]	2.3	70
WHO[b]	4	122

[a] GLWQI: Great Lakes Water Quality Initiative

[b] World Health Organization (WHO) emphasizes that values greater than 1 pg/kg bw/d are provisional because subtle effects may be occurring in some sections of the general population at intake rates of 1–4 pg/kg bw/day

Estimates of daily DLC intake by Tittabawassee River fish consumers (Table 6) were compared with the noncancer comparison value of 1 pg TEQ/kg/d arrived at by ATSDR and the World Health Organization (WHO). The equation comparing TEQ intake to the comparison value is provided in Appendix 6. Daily comparison values above 1 pg TEQ/kg/d are considered provisional by WHO and may cause measurable molecular level effects that may or may not be considered a negative health effect.

Values greater than 1.0 indicate the comparison value was exceeded and the hazard is not considered minimal (Table 9). For children, average and frequent consumers of Tittabawassee River fish exceeded comparison values for all diets by 1.3–23 times. The hazard quotient for the child scenario with frequent fish consumption was 1.5. For adult scenarios, average consumers of fish exceeded comparison values for all diets except diet "A" (walleye) by an estimated 1.6–3.8 times, whereas the adult scenarios with frequent fish consumption exceeded comparison values for all Tittabawassee River fish diets by an estimated 2.0–26 times. For the child and adult male scenario, the background exposure hazard quotient for frequent fish consumption was 1.5 and 1.1, respectively.

Table 9. Noncancer hazard quotient estimates, by scenario, for average and frequent consumers of Tittabawassee River fish (bolded numbers exceed 1.0).

Diet	Child Hazard quotient		Adult Female Hazard quotient		Adult Male Hazard quotient	
	Average	Frequent	Average	Frequent	Average	Frequent
Back-ground[a]	1.0	**1.5**	0.5	1.0	0.4	**1.1**
A	**1.3**	**3.1**	0.8	**2.0**	0.7	**3.0**
B	**2.5**	**8.9**	**1.6**	**7.1**	**1.6**	**9.7**
C	**5.2**	**23**	**3.7**	**18**	**3.8**	**26**
MIX	**2.8**	**10**	**1.8**	**8.2**	**1.8**	**11**

[a]: The average background fish tissue concentration for fish not collected from the Tittabawassee River was set to 0.74 pg TEQ/g of fish tissue (Schecter et al. 2001).

Toxicological Evaluation

Health Effects

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 assumed 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).

Exposure to low levels of DLCs in study animals 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, and neurodevelopmental effects (ATSDR 1998). Animal studies also have demonstrated that exposure to DLCs can cause reproductive damage, birth defects, decreased sperm counts, immune suppression, genital malformations, neurobehavioral effects, endometriosis, and behavioral change.

Whether people exposed to low levels of DLCs will experience the same health effects seen in animal studies is not known. However, the science suggests that DLCs have the potential to cause a wide range of adverse effects, including 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 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*."

The DLC exposure estimates calculated by MDCH suggest that people regularly eating Tittabawassee River fish will be exposed to greater amounts of DLCs than average U.S. residents. Estimated DLC intake rates from regular consumption of certain diets of Tittabawassee River fish exceeded ATSDR and WHO noncancer comparison values, suggesting the noncancer hazard was not minimal. Cancer estimates exceeded acceptable risk levels in the State of Michigan, suggesting people regularly eating certain diets of Tittabawassee River fish are at greater risk from DLC exposure.

<u>Childhood Health Considerations</u>

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 evaluated a child scenario for noncancer health risks. On the basis of this child exposure scenario, children who eat fish from the Tittabawassee River would have similar or slightly higher levels of risk than adults.

Cancer risk estimates typically are not conducted for children given that 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. Furthermore, MDCH recognizes that fetuses exposed in utero and infants exposed through breastfeeding may be exposed to relatively high concentrations. MDCH has used a 30-year exposure duration as a conservative estimate in cancer risk calculations to ensure that the most sensitive individuals are protected.

Conclusions

Past DLC exposures from consumption of Tittabawassee River fish were similar to or greater than current dioxin exposures from consumption of Tittabawassee River fish. Current estimates of DLC exposure suggest elevated cancer and noncancer risk levels. Therefore, past and current DLC exposures from consumption of certain diets of Tittabawassee River fish were and are a *public health hazard*. MDCH has issued a fish consumption advisory on Tittabawassee River fish since the 1970s. Fish consumption advisories are necessary for people who eat fish from the Tittabawassee River to minimize DLC exposures and associated risks.

Future DLC tissue concentration cannot be predicted from the current fish tissue data. Therefore, future DLC exposures from consumption of Tittabawassee River fish are an *indeterminate public health hazard*.

Recommendations

1. People who eat fish from the Tittabawassee River should follow the *Michigan Family Fish Consumption Guide.*
2. Efforts should be undertaken to make the Michigan fish consumption guidance more available to women of childbearing age, young children, and frequent consumers of Tittabawassee River fish within the Saginaw Bay Watershed.
3. Fillets from species of fish such as bullhead, northern pike, panfish, and suckers should be tested for DLCs.

Public Health Actions

1. MDCH will continue to issue its *Michigan Family Fish Consumption Guide*.
2. MDCH will undertake an outreach and education effort to fish consumers and the sensitive population.
3. MDEQ will continue monitoring fish from the Tittabawassee River, and MDCH will request that the MDEQ analyze less frequently tested fish species for DLCs.

If any citizen has additional information or health concerns regarding this health consultation, please contact MDCH's Environmental and Occupational Epidemiology Division, at 1-800-648-6942.

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Certification

This Tittabawassee River Fish Consumption Health Consultation was prepared by the Michigan Department of Community Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation was begun.

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

Appendix 1. Letter to Petitioners for Dow Midland dated November 2, 2001

ATSDR/DHAC/OD
2001 MAY 10 PM 12:05

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A-1 # 8241
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

John Steward
Draft response due
DHAC 5/24/01
Due OAA 5/30/01

May 1, 2001

Dr. Henry Falk
Assistant Administrator
Agency for Toxic Substances and Disease Registry (ATSDR)
1600 Clifton Road, NE (E28)
Atlanta, GA 30333

Dear Dr. Falk,

We are writing on behalf of our organizations to petition for a public health assessment of the population of Midland, Michigan, because of chronic and serious dioxin contamination. The primary source of this contamination is the Dow Chemical Company.

Our petition is prompted by the following facts, which have emerged over the last two decades:

- Results of soil sampling by the state Department of Environmental Quality (DEQ) in Midland have been surprising, and alarming. Although the state's residential cleanup criteria for dioxins in soil is 90 parts per trillion, of 37 samples taken in the community in 1996, almost a third had dioxin above that level. The areas that exceeded the residential cleanup standard included two elementary schools, an intermediate school, a high school and parks. **These are areas where the public has access and children play.** After release of these results, DEQ promised to resample community areas and determine potential human exposures.

- Instead of carrying through on its commitment, DEQ agreed with Dow's suggestion to use soils inside Dow's corporate center as a "surrogate" for the community. Levels found in 1998 sampling at the corporate center ranged from 66 to 476 parts per trillion, with an average of 136 parts per trillion. One particularly high dioxin hot spot was adjacent to a residential area east of the Dow facility.

- DEQ and Dow *still* refuse to keep commitments to characterize human exposures to dioxins and take appropriate protective actions – more than four years after the first sampling was done.

- There are other routes of exposure to dioxins in Midland. Dioxin contamination of fish in the Tittabawasee River below Midland is chronically high. According to the *Michigan Fish Contaminant Monitoring Program: 2000 Annual Report* issued by DEQ this winter, dioxin TEQ concentrations exceeded the "trigger level" for fish consumption warnings in all 10 carp collected in 1999 and in all 11 carp collected since 1992, and in 2 of 5 smallmouth bass. As a result, the state has tightened its advisory to warn against eating more than 1 meal per week for smallmouth bass from the river due to dioxin, and advises that women and children eat no smallmouth basis from the river due to elevated levels of dioxins and PCBs.

This data is simply the latest in a long line of disclosures about dioxin contamination of the community. For example, a 1985 multi-media risk assessment by the U.S. Environmental Protection Agency pointed to birth defects and cancer data suggesting elevated health effects in the Midland community, noted that the highest levels of dioxin in the nation were found in Tittabawasee River fish, and called for a comprehensive health study. To date, no such study has ever been done. Further, rather than taking action to protect the public from the serious soil contamination documented in the two most recent rounds of soil testing, the State of Michigan has continued to engage in private discussions with Dow Chemical Company about how to manage public relations. Despite repeated requests from our organizations for an independently-funded, state-commissioned health study and a plan to protect citizens from exposure to excessive levels of dioxins, the state has taken no such action.

It is abundantly clear that significant levels of dioxins and other hazardous materials, including PCBs, are present in the Midland community and in adjacent communities, where contaminants are transported from Dow via water and air. These contaminants may be ingested through fish, consumed in other food, absorbed through dermal contact with soils, and inhaled. 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 study health impacts in the community.

Sincerely,

Appendix 2. Map of Tittabawassee River and Surrounding Area

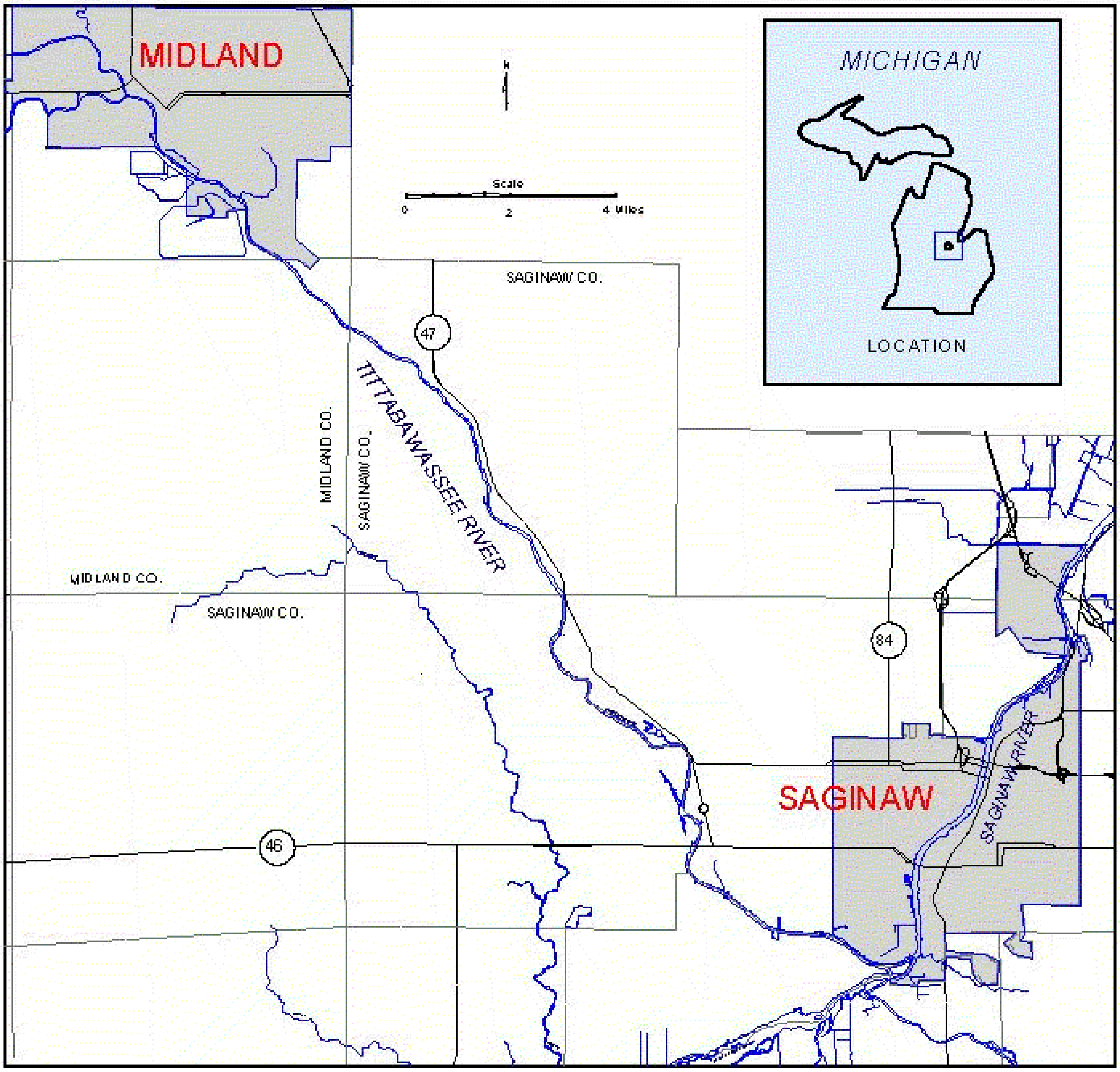

Figure 1: Tittabawassee River and Surrounding Area.

Appendix 3. Range of 2,3,7,8-TCDD Concentrations in Fillets
of Tittabawassee River Fish Sampled Downstream of the Dow Dam
and Grouped by Species and Year

MDCH compiled 2,3,7,8-TCDD data from several sources for fish sampled from the Tittabawassee River. Fish were taken not only downstream of the Dow Dam in Midland, but also upstream (e.g., Sanford Lake). Analytical results from upstream samples (not shown here) generally indicate substantially lower concentrations than those downstream of the dam. Data sources included the MDEQ Fish Contaminant Monitoring Program database (http://www.deq.state.mi.us/fcmp/default.asp), Dow Chemical's Web site (http://www.dow.com/facilities/namerica/michigan/dioxin/index.htm), and historic MDCH files showing results from other sampling efforts by regulatory agencies and Dow Chemical. The preponderance of fish tissue data is for carp and walleye (data tables follow). Historically, other species sampled include smallmouth and white bass (data shown in individual tables), and rock bass, northern pike, catfish, bullhead, sucker, crappie, and yellow perch (these species are shown in one table).

2,3,7,8-TCDD in Tittabawassee River carp fillets, by year (from locations downstream of Dow Dam in Midland; includes both skin-on and skin-off fillets; composite data not included)

Sample Year	N[a]	**2,3,7,8-TCDD range (ppt)**	**Data Source**
1977	1	ND[b]	Dow Chemical
1978	5	22–93	U.S. EPA
1983	25	12–525	National Dioxin Study (U.S. EPA)
1985	2	3.8–54	Dow Chemical
1987	3	4–9	Dow Chemical
1990	5	1.1–210	Dow Chemical
1992	5	1.4–209	Dow Chemical
	1	216	MDEQ (FCMP 92064)
1994	5	1.6–19.5	Dow Chemical
1999	10	3.4–15.6	MDEQ (FCMP 1999066)
2002	10	0.8–13.3	Dow Chemical
2003	10	0.54–23.4	MDEQ (FCMP 2003132)

[a] N = number of samples
[b] ND = not detected (detection limit = 40 ppt)

Carp fillet data may represent the worst-case scenario for dioxin contamination of fish that people, especially subsistence fishers, might catch from the Tittabawassee River and eat. This species is a bottom-feeder so it would take up dioxin from the sediment on the river bottom and from the river water and suspended sediments themselves. Also, carp are fatty and long-lived and more likely than leaner species (such as walleye) to develop a higher body burden of lipophilic chemicals. Data also exist for whole-fish contaminant levels in carp, which would be more useful in an ecologic risk assessment. Those data are not shown here because they are of limited use in assessing human exposure, but they are available from the MDEQ Fish Contaminant Monitoring Program database.

2,3,7,8-TCDD in Tittabawassee River walleye fillets, by year (from locations downstream of Dow Dam in Midland; includes both skin-on and skin-off fillets; composite data not included)

Sample Year	**N**[d]	**2,3,7,8-TCDD range (ppt)**	**Data Source**
1983	5	2.8–5.1	National Dioxin Study (U.S. EPA)
1985	18	ND[a,b]–9.3	Dow Chemical, FDA
1987	3	1.1–1.5	Dow Chemical
1990	8	0.8–3.2	Dow Chemical
1992	10	ND[c]–6.8	Dow Chemical
	2	1.46–1.67	MDEQ (FCMP 92064)
1994	10	0.9–5.3	Dow Chemical
2000	10	0.34–0.91	MDEQ (FCMP 2000093)
2002	10	0.9–3.1	Dow Chemical
2003	10	0.36–1.5	MDEQ (FCMP 2003132)

[a] ND = not detected
[b] Detection limit = 1.8 ppt
[c] Detection limit = 0.5 ppt
[d] N = number of samples

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2,3,7,8-TCDD in Tittabawassee River smallmouth bass fillets, by year (from locations downstream of Dow Dam in Midland; includes both skin-on and skin-off fillets; composite data not included)

Sample Year	**N**[a]	**2,3,7,8-TCDD range (ppt)**	**Data Source**
1985	1	5.8	Dow Chemical
1999	5	1.0–2.7	MDEQ (FCMP 1999066)
2000	10	0.83–3.3	MDEQ (FCMP 2000093)
2003	10	0.86–2.6	MDEQ (FCMP 2003132)

[a] N = number of samples

2,3,7,8-TCDD in Tittabawassee River white bass fillets, by year (from locations downstream of Dow Dam in Midland; includes both skin-on and skin-off fillets; composite data not included)

Sample Year	**N**[a]	**2,3,7,8-TCDD range (ppt)**	**Data Source**
1995	10	1.58–8.81	MDEQ (FCMP 95013)
2003	10	1.6–4.9	MDEQ (FCMP 2003132)

[a] N = number of samples

2,3,7,8-TCDD in other Tittabawassee River fish specimens, by year (from locations downstream of Dow Dam in Midland; includes both skin-on and skin-off fillets; composite data not included).				
Species	**Sample Year**	**N**[a]	**2,3,7,8-TCDD range (ppt)**	**Data Source**
Northern Pike	1985	1	16.5	FDA
Channel Catfish	2003	10	0.72–4.5	MDEQ (FCMP 2003132)
Catfish	1976	6	ND[b,c]–230	Dow Chemical
	1977	2	ND[d]–170	Dow Chemical
	1978	2	273–695	U.S. EPA
	1985	1	92	Dow Chemical
Sucker/White Sucker	1978	2	8–21	U.S. EPA
Yellow Perch	1978	1	ND[e]	U.S. EPA
Crappie	1977	3	40–90[f]	Dow Chemical
Bullhead	1977	3	20–140[f]	Dow Chemical
Rock Bass	1977	1	70[f]	Dow Chemical

[a] N = number of samples
[b] ND = Not detected
[c] Detection limit = 10-20 ppt
[d] Detection limit = 60 ppt
[e] Detection limit = 4 ppt
[f] Authors assumed detected tetra-isomers to be 2,3,7,8-TCDD.

Analytical techniques have evolved, resulting in increasingly lower detection limits. In addition, methods have been standardized. As analytical methods improved, different dioxin and furan congeners became identifiable and quantifiable. Earlier (up to the 1980s) reported concentrations of dioxins and other contaminants in fish probably are not comparable between years or laboratories. Earlier reported concentrations of 2,3,7,8-TCDD may have represented all tetra-isomers, whereas more recent analyses may report congener-specific concentrations.

With the advent of TEQs for dioxins and furans, scientists could calculate the total toxic equivalent value for a sample. Assuming that the 2,3,7,8-TCDD values above depict only the concentration of that specific congener and that other dioxins and furans were present, the TEQ concentration of the samples would have been greater than the value reported for 2,3,7,8-TCDD. Therefore, consumers of dioxin-contaminated fish probably were exposed to more DLCs than previously assumed.

Appendix 4. Equation and Inputs

to Estimate a U.S. National Average Background DLC Intake

MDCH estimated average national background dioxin estimates by inserting the values in Tables A, B, and C into the equations presented in Table D. The references for each value are provided. Where possible, the dioxin concentrations use zero for nondetections, which is the same method used in the Michigan fish consumption advisory.

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	0.067[b]	ppt TEQ whole weight	Winters et al. 1996
3	Dairy	0.238[c]	ppt TEQ whole weight	Schecter et al. 2001
4	Eggs	0.025[d]	ppt TEQ whole weight	Hayward & Bolger 2000
5	Freshwater Fish	0.741[e]	ppt TEQ whole weight	Schecter et al. 2001
6	Marine Fish	0.083[e]	ppt TEQ whole weight	Schecter et al. 2001
7	Milk	0.013[f]	ppt TEQ whole weight	Schaum et al. 2003
8	Pork	0.038[g]	ppt TEQ whole weight	Lorber et al. 1997
9	Poultry	0.059[h]	ppt TEQ whole weight	Ferrario et al. 1997
10	Soil	6	ppt TEQ dry weight	MDEQ 2004
11	Vegetable Fat	0.002[d]	ppt TEQ whole weight	Schrock et al. 1996
12	Water	0.00056[d]	ppq	Jobb et al. 1990

[a] Estimates include chlorinated dibenzo-*p*-dioxins and chlorinated dibenzofurans but do not include PCBs.
[b] Paper does not mention whether nondetections were encountered.
[c] Average includes butter, cheese, and ice cream with nondetections (ND) = 0.
[d] Value reported as ND = 0.
[e] Values adjusted so nondetections (ND) equal 0. Freshwater fish values ND=0 were 8.6% lower than when ND=1/2; marine fish values were 68% lower when ND=0. The freshwater fish concentration of 0.810 pg/g was adjusted to 0.74; the marine fish concentration 0.198 was adjusted to 0.083 pg/g.
[f] Value for the Midwest including Michigan. Value was adjusted downward by 15% to estimate ND=0.
[g] Value was adjusted to a tissue sample containing 8.25% lipid content intended to represent a non-lean pork chop and ND=0.
[h] Value originally measured in chicken fat (80% lipid) and was adjusted to 11% lipid with ND=0. This value represents an average of four estimates.

Table B. Ingestion and contact rates by media.

NO.	Media	Units	Child	Adult Female	Adult Male	References
1	Air (inhalation)	m^3/d	13.5[f]	11.3[h]	15.2[j]	U.S. EPA, 1997b
2	Beef	g/d	63	79	86	See Table C, Below
3	Dairy	g/d	47	56	56	See Table C, Below
4	Eggs	g/d	16	25	27	See Table C, Below
5	Freshwater Fish					
	Average[a]	g/d	4.08	6.93	9.05	U.S. EPA 2002
	Frequent[b]	g/d	20.11	38.04	66.36	
6	Marine Fish					
	Average[a]	g/d	5.63	10.08	13.52	U.S. EPA 2002
	Frequent[b]	g/d	41.64	71.16	106.67	
7	Milk	g/d	398	243	252	See Table C, Below
8	Pork	g/d	18	26	28	See Table C, Below
9	Poultry	g/d	25	44	45	See Table C, Below

10a	Soil Ingestion[c]	g/d	0.1	0.05	0.05	U.S. EPA, 1997a
10b	Soil Dermal Contact[d]	g/d	0.025	0.121	0.121	U.S. EPA, 1997a
11	Vegetable Fat[e]	g/d	7.37	7.37	7.37	U.S. EPA, 1997b
12	Water ingestion	L/d	0.74[g]	1.4[i]	1.4[i]	U.S. EPA, 1997a

[a] U.S. EPA 2002, 95% upper confidence limit on the mean fish consumption rate.
[b] U.S. EPA 2002, 90% upper bound on the 95th percentile.
[c] U.S. EPA 1997a, Table 4-23.
[d] U.S. EPA 1997a, Tables 6-4 and 6-12, calculated an average value for adults and children.
[e] U.S. EPA 1997b, Table 11-26 and 11-27, mean total fat intake (81.9 g/d) times the percentage of fat intake from vegetables (9%), therefore, 81.9 * 0.09 = 7.37 g/d.
[f] U.S. EPA 1997a, Table 5-23, mean value for 9- to 11-year-olds for males and females combined.
[g] U.S. EPA 1997a, Table 3-30, mean value for 1- to 10-year-olds.
[h] U.S. EPA 1997a, Table 5-23, *Adults-Female*.
[i] U.S. EPA 1997a, Table 3-30, *Adults.*
[j] U.S. EPA 1997a, Table 5-23, *Adults–Male*.

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. Parameters and equation for background dioxin intake calculations.

Parameter in Equation	Parameter Selection (units)	Description
Background Intake	$\sum_{i=1}^{12} X_i$, Where X is the intake equation for each dioxin source, i listed in Table A.	Summation of the background intake estimates. Two types of background estimates were calculated: a) Background with freshwater fish consumption included (Bck) b) Background without freshwater fish consumption included (Bcknf)
Intake Equation	$X = \left(\frac{C \times Ir \times Ed \times Abs}{Bw \times At} \right)$	Intake Equation resulting in either daily (pg/kg/d) or monthly (pg/kg/m) intake rates.
(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 (see table for units)	Ingestion/contact rates for each media by human exposure scenario.
(Bw) Body Weight	Table 3 in Text on page 5 (kg)	Average body weights were assigned to scenarios based on age and/or gender of the scenario.
(Abs) Absorption into blood stream	Absorption = 100% (unitless) Dermal Contact = 3% (unitless)	MDCH assumed 3% absorption across skin. MDCH assumed that 100% of the ingested TEQ will enter the blood stream (Schlummer et al. 1998, Harrad et al. 2003, Moser et al. 2001).
	<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 grams of chemical per day basis, thus

			exposure is occurring during each day of the scenario.
		CANCER ASSUMPTIONS	
Exposure Duration	70 years		Background exposures occur for the entire life of the individual.
Averaging Time	70 years		Assumed average length of life.

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Appendix 5. Equations and Parameters for DLC Intake Estimates from the Consumption Tittabawassee River Fish

Parameter	Parameter Selection (units)	Description
Intake Equation	$Intake = \left(\left(\frac{C \times Ir \times Ed}{Bw \times At}\right) \times Abs\right) + Bcknf$	Intake Equation resulting in either daily (pg/kg/d) or monthly (pg/kg/m) intake rates.
(C) Concentration in Diet	Table 5 in text on page 6 (pg TEQ/g)	Average dioxin TEQ concentration in the Tittabawassee diet of fish.
(Ir) Ingestion Rate	Table 3 in text on page 5 (g/day) or (g/month)	Amount of daily fish consumption for average or frequent fish consumers in each human exposure scenario.
(Bw) Body Weight	Table 3 in text on page 5 (kg)	Average body weights were assigned to scenarios on the basis of age and/or sex of the scenario population.
(Abs) Absorption into bloodstream	100% (unitless)	MDCH is assuming that 100% of the TEQ intake will enter the bloodstream (Schlummer et al. 1998, Harrad et al. 2003, Moser et al. 2001.
(Bcknf) Background Dioxin Exposure Without Freshwater Fish Consumption Included	Table 4 in text on page 5 (pg TEQ/kg/d) or (pg TEQ/kg/month)	MDCH estimates of nationwide daily and monthly dioxin exposure rates that do not include dioxin exposure from freshwater fish consumption. This background rate, which does not include freshwater fish consumption, is added to dioxin exposure from consumption of Tittabawassee River fish (i.e., freshwater fish consumption).
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.

	NONCANCER ASSUMPTIONS	
(Ed) Exposure Duration	> 365 days (days)	DLC exposure from fish consumption is generally thought of in terms of chronic exposure (>365 days). DLCs accumulate in body tissues because the body does not metabolize and excrete these chemicals quickly.
(At) Averaging Time	Equal to exposure duration (days)	Exposures are annualized and calculated on a grams-of chemical-per-day basis; thus exposure occurs during each day of the scenario.
	CANCER ASSUMPTIONS	
Exposure Duration	30 years	Upper bound of living at a single residence.
Averaging Time	70 years	Average length of life.

Appendix 6. Cancer and Noncancer Assessment Equations

Assessment	Equation	Description
Noncancer	Hazard Quotient Equation HQ = TEQ Intake / Comparison Value	TEQ intakes are listed in Table 6; comparison values are listed in Table 8. 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 in Table 6 in text, page 6 CSF = Cancer Slope Factor of 0.000075 $(pg/kg/d)^{-1}$	Cancer Slope Factor is a measure of how toxic dioxin is with regards to causing cancer. The current U.S. EPA CSF is used in this consultation. The risk calculation is presented in context of the number of additional cancers per 100,000 exposed persons.