Public Health Assessment

Final Release

Kalamazoo River/Enbridge Spill: Evaluation of Kalamazoo River surface water and fish after a crude oil release
(Calhoun and Kalamazoo Counties, Michigan)

Prepared by the
Michigan Department of Community Health

JUNE 2, 2014

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR's Cooperative Agreement Partner pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 60-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Foreword

The Michigan Department of Community Health (MDCH) conducted this evaluation under a cooperative agreement with federal Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR conducts public health activities (assessments/consultations, advisories, education) at sites of environmental contamination. The purpose of this document is to identify potentially harmful exposures and recommends actions that would minimize those exposures. This is not a regulatory document and does not evaluate or confirm compliance with laws. This is a publicly available document and is provided to the appropriate regulatory agencies for their consideration.

The following steps are necessary to conduct public health assessments/consultations:

- Evaluating exposure: MDCH toxicologists begin by reviewing available information about environmental conditions at the site: how much contamination is present, where it is found on the site, and how people might be exposed to it. This process requires the measurement of chemicals in air, water, soil, or animals. Usually, MDCH does not collect its own environmental sampling data. We rely on information provided by the Michigan Department of Environmental Quality (MDEQ), U.S. Environmental Protection Agency (EPA), and other government agencies, businesses, and the general public.
- Evaluating health effects: If there is evidence that people are being exposed – or could be exposed – to hazardous substances, MDCH toxicologists then determine whether that exposure could be harmful to human health, using existing scientific information. The report focuses on public health – the health impact on the community as a whole.
- Developing recommendations: In its report, MDCH outlines conclusions regarding any potential health threat posed by a site, and offers recommendations for reducing or eliminating human exposure to contaminants. If there is an immediate health threat, MDCH will issue a public health advisory warning people of the danger, and will work with the appropriate agencies to resolve the problem.
- Soliciting community input: The evaluation process is interactive. MDCH solicits and considers information from various government agencies, parties responsible for the site, and the community. If you have any questions or comments about this report, we encourage you to contact us.

Please write to: Toxicology and Response Section
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For more information, please visit:
www.michigan.gov/mdch-toxics

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Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BaP	benzo(a)pyrene
BW	Body weight
CR	Consumption rate
CSF	Cancer slope factor
DL	Detection limit
DRO	diesel range organics
EPA	United States Environmental Protection Agency
FDA	United States Food and Drug Administration
GRO	gasoline range organics
kg	kilogram
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
mg/L	milligrams per liter
NA	not available
NLM	United States National Library of Medicine
NRC	National Response Center
NS	no samples
ORO	oil range organics
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PHA	Public Health Assessment
ppb	Parts per billion
ppm	Parts per million
RDWC	Residential Drinking Water Criteria
RfD	reference dose
RL	Risk level
UCL	upper confidence limit on the mean
µg/L	micrograms per liter

Summary

Kalamazoo River and Morrow Lake surface water sampling began in July 2010. The sampling was in response to an oil spill from a pipeline operated by Enbridge Energy Partners, LLP (Enbridge). The Michigan Department of Community Health (MDCH) issued an advisory against swimming or fishing in the oil-impacted stretch of the Kalamazoo River and Morrow Lake. The local health departments (in Calhoun and Kalamazoo counties) banned recreational use of the river to prevent people's exposure. This Public Health Assessment (PHA) evaluates chemical levels in surface water and fish. The surface water data were collected between July 2010 and April 2012 from the Kalamazoo River and Morrow Lake. Fish were collected from the Kalamazoo River and Morrow Lake in 2010 and 2011.

MDCH has reached the following conclusions about chemical levels in Kalamazoo River and Morrow Lake surface water and fish:

1. *Chemical levels found in surface water are not expected to cause long-term harm to people's health. People may have temporary health effects, such as skin irritation, from contact with oil sheen or tar globules in the water.* Oil-related and non-oil related chemicals were measured in the surface water. Only a very few of these chemicals were detected above health-protective screening levels in surface water samples. These chemicals were mostly polycyclic aromatic hydrocarbons. People are not expected to be exposed to levels that would cause long-term health concerns. However, if people have contact with these chemicals or the oil sheen and tar globules in the river, they may develop temporary health effects, such as skin irritation.

   Next steps: MDCH will continue to review new surface water data.

2. *Oil-related chemical levels found in fish from the Kalamazoo River and Morrow Lake will not harm people's health. However, MDCH has issued fish consumption guidelines because of levels of mercury and polychlorinated biphenyls (PCBs) levels found in the filets.* Fish were collected from Marshall Pond, Ceresco Impoundment, and Morrow Lake. Marshall Pond is upstream of the oil spill. Chemical levels in Marshall Pond fish filets were similar to levels found in Ceresco Impoundment and Morrow Lake fish. Two chemicals not related to the oil spill, mercury and PCBs, were found in the fish filets. MDCH recommends that people limit the amount of certain Kalamazoo River and Morrow Lake fish they eat. (Guidelines listed in this PHA are listed in the 2014-2015 Eat Safe Fish Guide [formerly the Michigan Fish Advisory].) Current guidelines can be found at: www.michigan.gov/eatsafefish.

   Next steps: MDCH will evaluate new fish data and issue fish consumption guidelines as needed.

Purpose and Health Issues

The purpose of this Public Health Assessment (PHA) is to determine if people are or may be exposed to chemicals in the Kalamazoo River or Morrow Lake surface water or fish and if any

potential exposure is harmful to people's health. Within days of the oil spill in July 2010, surface water samples were collected from the Kalamazoo River and Morrow Lake. Surface water samples were collected for the rest of 2010, 2011, and 2012 (and continues as of November 2, 2012). Fish from the Kalamazoo River (Marshall Pond and Ceresco Impoundment) and Morrow Lake were collected in 2010 and 2011. Ecological assessment, such as determining effects to fish, is beyond the scope of this PHA. This PHA does not evaluate or confirm regulatory compliance, but determines if any potentially harmful human exposures are occurring or may occur in the future.

This PHA was available for public comment from September 30 to November 14, 2013. MDCH did not receive any comments.

Background

In July 2010, more than 800,000 gallons of crude oil flowed into a wetland area near Talmadge Creek and into the creek, which is a tributary of the Kalamazoo River. The oil was from a 30-inch pipeline near the city of Marshall, Calhoun County, Michigan operated by Enbridge Energy Partners, LLP (Enbridge). Enbridge reported the spill to the National Response Center (NRC), which notified the United States Environmental Protection Agency (EPA), among other agencies.

The EPA was the lead agency for response to this spill and on July 27, the Federal On-Scene Coordinator and Incident Commander issued the EPA Removal Order. Using guidelines of the Incident Command System[1], a Unified Command was established later that week. Members of the Unified Command included federal, state and local agencies, along with Enbridge representatives. At the request of the EPA Incident Commander, MDCH staff deployed to the Command Center to provide public health support.

The spilled oil was eventually contained at Morrow Lake, which was more than 37 miles downstream from the spill (MDEQ 2010a). See Figure 1 for the extent of the oil spill. At the time of the spill, Talmadge Creek and the Kalamazoo River were between 25- and 50-year flood levels due to rain that had fallen during the previous days. Because the river and creek were at high water levels, oil flowed into overbank areas, wetlands, and floodplains.

In July 2010, Calhoun County Public Health and Kalamazoo County Health and Community Services Department issued a ban on recreational river use. MDCH issued a swimming and fishing advisory and a "do not eat" guideline for fish in the river.[2] In June 2012, a majority of the river was re-opened for recreational use by the county health departments and MDCH lifted the advisory and guideline. MDCH recommended that people follow the pre-spill fish consumption guidelines for the Kalamazoo River and Morrow Lake.

[1] The Incident Command System is a management system for incidents of all sizes and types. This system is used when one agency is responding to an incident and can be scaled up for when many agencies are responding to an incident.

[2] The MDCH guideline extended from downstream (west) of I-69 on the Kalamazoo River to the west end of Morrow Lake.

Figure 1: Overview of the areas of Talmadge Creek and the Kalamazoo River impacted by the July 2010 oil spill (Calhoun and Kalamazoo Counties, Michigan).The lines indicate the area impacted by the July 2010 oil spill and the fish indicate locations where fish were collected (one location upstream of the oil spill: Marshall Pond, and two locations in the area impacted by the oil spill: Ceresco Impoundment and Morrow Lake).

Discussion

This PHA evaluates two ways people may be exposed to chemicals. One from contact with the Talmadge Creek, Kalamazoo River, and Morrow Lake surface water and the second from eating fish caught from the Kalamazoo River or Morrow Lake. (Talmadge Creek is not fishable.)

Along with the chemicals detected in the Michigan Department of Environmental Quality's (MDEQ) analysis of the oil (MDEQ 2010b), surface water samples were tested for a variety of other chemicals. Some may have been in the oil, but some are naturally occurring or may have been previously present in the surface water. MDCH tested fish filets for chemicals found in the oil, as well as chemicals that were previously found in fish from the Kalamazoo River and Morrow Lake before the oil spill.[3] Table 1 contains the chemicals identified in the MDEQ's analysis.

Table 1: Chemicals detected in the Michigan Department of Environmental Quality's (MDEQ) analysis of the crude oil were:

Inorganic chemicals (metals)[4]	Organic chemicals
Beryllium	1,2,3-Trimethylbenzene
Iron	1,2,4-Trimethylbenzene
Mercury	1,3,5-Trimethylbenzene
Molybdenum	2-Methylnaphthalene
Nickel	Benzene
Titanium	Cyclohexane
Vanadium	Ethylbenzene
	Isopropylbenzene
	Naphthalene
	n-Propylbenzene
	Phenanthrene
	p-Isopropyltoluene
	sec-Butylbenzene
	Toluene
	Xylenes, Total

Environmental Contamination

Surface water

Data presented in this PHA were collected from July 2010 to April 2012. These data were obtained from the EPA's Scribe data base. In 2010, MDCH advised people to avoid contact with the oil and the local health departments banned recreational river use. Levels of chemicals

[3] The fish were tested for chemicals previously found to ensure that the presence of the oil or any cleanup activities (changes to the river or lake) did not increase the chemical levels in the fish.

[4] Aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, lead, lithium, manganese, and zinc were not detected in samples of the crude oil (MDEQ 2010b).

measured in surface water samples collected in 2010 are provided in Appendix A (Tables A-2 through A-8). These data are not evaluated in this PHA because the oil floating on Talmadge Creek, the Kalamazoo River, and Morrow Lake was removed in the cleanup conducted in 2010. The 2011 data are evaluated here as it provides information about chemical levels across four seasons of river and lake conditions (temperature, water levels, etc.). Data from 2012 provide information about conditions within a few months prior to the Kalamazoo River and Morrow Lake opening.

Surface water sampling results were compared to health-based screening levels. These screening levels are expected to be protective for everybody, including children. People's actual exposure would most likely be lower than the exposure used in the screening levels. If the levels in the surface water were below the screening level, no further evaluation was necessary. If chemical levels were above the screening level, those chemicals were evaluated further. All screening levels are listed Table A-1 and described in Appendix A.

Samples were collected throughout the impacted area of the Kalamazoo River and Morrow Lake. Surface water was collected from more than 30 locations throughout the impacted area in 2011. From January to April 17, 2012, surface water samples were collected from 27 locations throughout the area impacted by the oil spill. Data was grouped into four month intervals: January to April 2011, May to August 2011, September to December 2011, and January to April 17, 2012. (Data from 2010 is in Appendix A.)

Table 2 presents the data from the surface water samples collected from January 2011 to April 2011. Screening levels are not available for diesel range organics (DRO), gasoline range organics (GRO), oil range organics (ORO), p-isopropyltoluene, and titanium. These chemicals were not detected in most samples collected. As multiple laboratories and methods were used to analyze for these chemicals, reporting limits were presented when the chemical was not detected. These analytes will be discussed in the "Analytes with No Screening Levels" section. No analytes were over available screening levels.

Results for the surface water samples collected between May and August 2011 are presented in Table 3. DRO, GRO, methyl iodide, ORO, p-isopropyltoluene, and titanium have no screening levels and will be discussed in the "Analytes with No Screening Levels" section. Of the remaining analytes listed in Table 3, only benzo(a)pyrene was detected in surface water over the screening level of 2 µg/L. All other chemicals in Table 3 were not detected, but had reporting limits over the screening level (reporting limits were presented as minimum and maximum in the "Not detected" column). Reporting limits are the amount of a chemical that can accurately be detected and its concentration reliably measured. Analytes may be present in the sample below the reporting limit, but will be discussed if the largest reporting limit is over the screening level.

Acenapthylene was not detected in any of the surface water samples collected between May to August 2011; however, the reporting limit was above the screening level for two out of 503 samples. The average of these samples is 2.6 µg/L.[5] This average is well below the screening level of 52 µg/L.

[5] All values (detected and non-detected) were included in the calculation. This value was calculated with EPA's ProUCL 4.1 software.

Indeno(1,2,3-c,d)pyrene was detected in only one of the 503 samples collected between May and August 2011. Only reporting limits from two of the samples were above the screening level. The amount detected, 2.1 µg/L, was below the screening level of 20 µg/L. The average level of indeno(1,2,3-c,d)pyrene was 2.2 µg/L,[6] which is under the screening level. Acenapthylene and indeno(1,2,3-c,d)pyrene will not be discussed further. Benzo(a)pyrene, dibenz(a,h)anthracene, 1,2,3-trichloropropane, and trans-1,4-dichloro-2-butene will be discussed below.

Table 4 presents the analytes over or with no screening levels in surface water samples collected between September and December 2011. DRO, GRO, methyl iodide, ORO, and p-isopropyltoluene will be discussed in the "Analytes with No Screening Levels" section. Of the remaining analytes, only benzo(a)pyrene was detected in surface water samples. All other analytes had reporting limits that were over the screening levels.

For the 631 surface water samples collected between May and December 2011 (Tables 3 and 4), benzo(a)pyrene was only detected in three samples. Only two of the detected samples were over the screening level of 2 µg/L. The average level of benzo(a)pyrene in the surface water was about 2 µg/L.[7] Benzo(a)pyrene will be discussed further in the "Exposure Pathways" section.

For the 631 surface water samples collected between May and December 2011 (Tables 3 and 4), dibenz(a,h)anthracene was not detected in any of the samples. For the samples where dibenz(a,h)anthracene was not detected, 131 samples had reporting limits over the screening level of 2 µg/L. The average level for all the samples tested for dibenz(a,h)anthracene was 2.2 µg/L.[8] This analyte will be discussed further in the "Exposure Pathways" section.

No analytes were detected in surface water samples collected from January to April 17, 2012 (Table 5). Methyl iodide and p-isopropyl toluene will be discussed in the "Analytes with No Screening Levels" section. The reporting limits were over the screening levels for two analytes, 1,2,3-trichloropropane and trans-1,4-dichloro-2-butene. These analytes will be discussed in the "Exposure Pathways" section.

[6] All values (detected and non-detected) were included in the calculation. This value was calculated with EPA's ProUCL 4.1 software. The EPA's ProUCL software can be found at: http://www.epa.gov/osp/hstl/tsc/software.htm#Download.

[7] If all values (detected and non-detected) were included in the calculation, the average was 1.9 µg/L. If the reporting limits were identified as non-detects, the average was 2.2 µg/L. These values were calculated with EPA's ProUCL 4.1 software.

[8] The average was calculated, using the EPA's ProUCL 4.1 software, using the reporting limits because dibenz(a,h)anthracene was not detected in any of the samples.

Table 2: Levels of analytes (in microgram per liter [µg/L]) with no screening levels in surface water samples collected January 2011 through April 2011.

Analyte	Total number of samples	Detected			Not detected[a]		
		Number of samples	Minimum level	Maximum level	Number of samples	Minimum reporting limit	Maximum reporting level
Diesel Range Organics (DRO)	337	0	ND[b]	ND	337	100	100
Gasoline Range Organics (GRO)	334	0	ND	ND	334	200	200
Oil Range Organics (ORO)	70	67	48	220	3	100	100
p-Isopropyltoluene	337	0	ND	ND	337	1	2
Titanium	656	325	0.55	14	331	1.0	1.0

a = These chemicals were not detected. The minimum and maximum levels were the reporting limits for the chemicals.
b = These chemicals were not detected in the samples (ND = not detected).

Table 3: Levels of analytes (in microgram per liter [µg/L]) over or with no screening levels in surface water samples collected May 2011 through August 2011.

Analyte	Screening level	Total number of samples	Detected				Not detected[a]			
			Number of samples	Minimum level	Maximum level	Samples over screening level	Number of samples	Minimum reporting limit	Maximum reporting limit	Samples over screening level
1,2,3-Trichloropropane	0.07	9	0	ND[b]	ND	NA	9	**1**	**1**	9
Acenaphthylene	52	503	0	ND	ND	NA	503	1	**100**	2
Benzo(a)pyrene	2	503	2	**2.1**	**3.4**	2	501	1	**20**	259
Dibenz(a,h)anthracene	2	503	0	NA	NA	NA	503	1	**40**	130
Diesel Range Organics (DRO)	NA	537	3	7,300	40,000	NA	534	100	1,000	NA
Gasoline Range Organics (GRO)	NA	537	0	ND	ND	NA	537	200	200	NA
Indeno(1,2,3-c,d)pyrene	20	503	1	2.1	2.1	0	502	1	**40**	2
Methyl iodide	NA	9	0	ND	ND	NA	9	1	1	NA
Oil Range Organics (ORO)	NA	537	7	440	170,000	NA	530	100	100	NA
p-Isopropyltoluene	NA	537	1	0.41	0.41	NA	536	2	5	NA
Titanium	NA	526	526	1.2	49	NA	0	NA	NA	NA
trans-1,4-Dichloro-2-butene	0.0012	9	0	ND	ND	NA	9	**5**	**5**	9

Bold values are above the screening levels.
a = These chemicals were not detected. The minimum and maximum levels were the reporting limits for the chemicals.
b = "NA" indicates that no screening levels were available or no values were available.

Table 4: Levels of analytes (in microgram per liter [µg/L]) over or with no screening levels in surface water samples collected September 2011 through December 2011.

Analyte	Screening level	Total number of samples	Detected				Not detected[a]			
			Number of samples	Minimum level	Maximum level	Samples over screening level	Number of samples	Minimum reporting limit	Maximum reporting limit	Samples over screening level
1,2,3-Trichloropropane	0.07	128	0	ND[b]	ND	NA	128	**1**	**1**	128
Benzo(a)pyrene	2	128	1	1	1	0	127	1	**5**	1
Dibenz(a,h)anthracene	2	128	0	ND	ND	NA	128	2	**5**	1
Diesel Range Organics (DRO)	NA	38	1	140	140	NA	37	100	100	NA
Gasoline Range Organics (GRO)	NA	8	0	ND	ND	NA	8	200	200	NA
Methyl iodide	NA	128	0	ND	ND	NA	128	1	1	NA
Oil Range Organics (ORO)	NA	38	5	260	710	NA	33	100	100	NA
p-Isopropyltoluene	NA	128	1	9.5	9.5	NA	127	5	5	NA
trans-1,4-Dichloro-2-butene	0.0012	128	0	ND	ND	NA	128	**1**	**1**	128

Bold values are above the screening levels.
a = These chemicals were not detected. The minimum and maximum levels were the reporting limits for the chemicals.
b = "NA" indicates that no screening levels were available or no values were available.

Table 5: Levels of analytes (in microgram per liter [µg/L]) with reporting limits over or with no screening levels in surface water samples collected January 2011 through April 17, 2012. No analytes were detected in these samples.

Analyte	Screening level	Not detected[a]			
		Number of samples	Minimum reporting limit	Maximum reporting limit	Samples over screening level
1,2,3-Trichloropropane	0.07	24	**1**	**1**	24
Methyl iodide	NA[b]	24	1	1	NA
p-Isopropyltoluene	NA	24	5	5	NA
trans-1,4-Dichloro-2-butene	0.0012	24	**1**	**1**	24

Bold values are above the screening levels.
a = These chemicals were not detected. The minimum and maximum levels were the reporting limits for the chemicals.
b = "NA" indicates that no screening levels were available or no values were available.

Fish from Marshall Pond, Ceresco Impoundment, and Morrow Lake

Fish were collected from three locations in 2010 and 2011. One location, Marshall Pond, is upstream of the spill and provides background levels of oil-related chemicals. Two locations, Ceresco Impoundment and Morrow Lake, were within the stretch of the Kalamazoo River impacted by the crude oil spill. Table 6 presents the fish species collected in 2010 and 2011 from these three locations. Fish filets were analyzed for nickel, vanadium, 21 individual polycyclic aromatic hydrocarbons (PAHs), mercury, and 83 polychlorinated biphenyl (PCB) congeners.[9] Nickel, vanadium, and a few of the PAHs were found in samples of the oil that spilled. Mercury and PCBs were measured to ensure that the oil spill, or the resulting clean-up activities, did not cause changes to chemical levels in the fish.

Table 6: Fish collected from the locations in the Kalamazoo River in 2010 and 2011.

Location	Collected in 2010 (number of fish)	Collected in 2011 (number of fish)
Marshall Pond	Carp (10) and Smallmouth Bass (10)	Carp (10), Largemouth Bass (10), Rock Bass (10), and Smallmouth Bass (10)
Ceresco Impoundment	Carp (10) and Rock Bass (10)	Carp (10), Rock Bass (5), Smallmouth Bass (10)
Morrow Lake	Bluegill (6[a]), Carp (10), and Rock Bass (8)	Bluegill (3[b]) and Carp (10)

a = Ten bluegill were collected in 2010 from Morrow Lake. The 6 bluegill filet samples include 3 composite samples (one composed of 3 fish filets, one composed of 2 fish filets, and one composed of 2 fish filets) and filets from three individual fish.
b = Ten bluegill were collected in 2011 from Morrow Lake. The 3 samples include 2 composite samples (one composed of 6 fish filets and one composed of 3 fish filets) and one individual filet.

MDCH has established fish consumption screening levels for mercury and PCBs. As no fish consumption screening levels were available for PAHs, nickel, and vanadium, MDCH calculated preliminary fish consumption screening levels using the assumption that a person would eat 16 *MI Servings* per month, which is the least restrictive consumption guideline category.[10] The screening level for benzo(a)pyrene and the carcinogenic PAHs grouped with benzo(a)pyrene, called BaP equivalent values,[11] was 0.9 ppb. For the other PAHs, nickel, and vanadium the screening level was 2,700 ppb.

Nickel and vanadium were not detected in any of the filets from fish collected in either 2010 or 2011 from Marshall Pond, Ceresco Impoundment, or Morrow Lake. The detection limit for nickel was 600 parts per billion (ppb). The detection limit for vanadium was 200 ppb. As there was no difference in the nickel and vanadium levels in fish collected from the three locations and

[9] Some other organochlorine chemicals are measured when PCBs are measured, but no fish consumption guidelines are issued due to these chemicals.
[10] MDCH's standard exposure assumptions and equations for calculating fish consumption guidelines are available at: www.michigan.gov/eatsafefish under "Reports and Science." The number of ounces in a *MI Serving* changes with body weight. For example, a *MI Serving* is 8 ounces for an 80 kilogram (kg) person, 4 ounces for a 40 kg person, and 2 ounces for a 20 kg person.
[11] Along with benzo(a)pyrene, six other PAHs (benzo(b)fluoranthene, benzo(a)anthracene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene) are included in the benzo(a)pyrene (BaP) equivalent values.

the levels were not above the screening level, no fish consumption guidelines are necessary for nickel and vanadium. Appendix B contains additional discussion.

Fish filets were tested for 21 PAHs. Seven of the PAHs can be evaluated as a group by relating the amount present to an equivalent amount of benzo(a)pyrene (BaP equivalent value). These seven are benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. See Appendix B for further details. BaP equivalent values are presented in Table 7. (See Table B-1, -2, and -3 in Appendix B for individual chemical levels.) For most of the samples, the PAHs included in the BaP equivalent value were not detected. These PAHs were only detected in carp and rock bass from Marshall Pond; carp from Ceresco Impoundment; and bluegill from Morrow Lake. The maximum BaP equivalent value was 1.26 ppb, from rock bass collected in Marshall Pond (a location upstream of the spill). While the maximum level is over the screening level of 0.8 ppb, an upper-bound estimate of the average concentration, called the 95% upper confidence limit of the mean (UCL), for all the rock bass collected from Marshall Pond (0.7 ppb) is not. No fish consumption guidelines are necessary.

The other fourteen PAHs were evaluated individually (1-methylnaphthalene, 1-methylphenanthrene, 2,6-dimethylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(e)pyrene, benzo(g,h,i)perylene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene). The highest levels of these PAHs were found in carp collected from Ceresco Impoundment in 2010 (naphthalene at 16.1 ppb) and Marshall Pond in 2010 (acenaphthene at 14.91 ppb). These levels are well below the screening level of 2,300 ppb.

No fish consumption guidelines are necessary due to the PAHs levels. Appendix B contains additional discussion.

Table 7: Range of PAHs (in parts per billion [ppb]) in fish collected in 2010 and 2011 from Marshall Pond, Ceresco Impoundment, and Morrow Lake.

Fish	Range (minimum and maximum) of PAHs (in ppb)					
	Marshall Pond		Ceresco Impoundment		Morrow Lake	
	BaP equivalent value[a]	Other PAHs[b]	BaP equivalent value[a]	Other PAHs[b]	BaP equivalent value[a]	Other PAHs[b]
Bluegill	NS[c]	NS	NS	NS	0.24-0.81[e]	0.2 (DL)[d] - 3.23
Carp	0.46[e]	0.2 (DL) - 14.91	0.46-0.67[e]	0.2 (DL) - 16.1	0.46	0.2 (DL) - 6.58
Largemouth Bass	0.46	0.2 (DL) - 2.92	NS	NS	NS	NS
Smallmouth Bass	0.46	0.2 (DL) - 4.67	0.46	0.2 (DL) - 6.96	NS	NS
Rock Bass	0.2-1.26[e]	0.2 (DL) - 8.99	0.46	0.2 (DL) - 7.5	0.46	0.2 (DL) - 3.37

a = The individual PAHs included in the BaP equivalent values are benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. See Appendix B for a description of the BaP equivalent values. Unless otherwise noted, these PAHs were not detected.
b = These PAHs are 1-methylnaphthalene, 1-methylphenanthrene, 2,6-dimethylnaphthalene, 2-methylnaphthalene, acenaphthene, acenaphthylene, anthracene, benzo(e)pyrene, benzo(g,h,i)perylene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene.
c = "NS" indicates that the fish were not sampled.
d = The value was at the detection limit (DL).
e = At least one of the PAHs was detected.

Tables 8 and 9 present the PCB and mercury levels, respectively, in fish collected from Marshall Pond, Ceresco Impoundment, and Morrow Lake. Based on the levels (95% UCLs) of PCBs and mercury measured in the fish filets, fish consumption guidelines are needed for certain fish species. The fish consumption guidelines are located in the discussion following Table 9.

Table 8: Minimum, Maximum, and 95% Upper Confidence Limit of the mean (UCL) in parts per million (ppm) of polychlorinated biphenyls (PCBs), in fish collected in 2010 and 2011 from Marshall Pond, Ceresco Impoundment, and Morrow Lake.

Fish	Levels of PCBs (in ppm)								
	Marshall Pond			Ceresco Impoundment			Morrow Lake		
	2010	2011	95% UCL[a]	2010	2011	95% UCL[a]	2010	2011	95% UCL[a]
Bluegill	NS[b]	NS	NA[c]	NS	NS	NA	0.0054-0.0162	0.0019-0.0074	0.01
Carp	0.001-0.0908	0.0031-0.0826	0.04	0.0139-0.2448	0.0035-0.066	0.12	0.0519-0.3041	0.0697-0.8292	0.55
Largemouth Bass	NS	0.001-0.0126	0.01	NS	NS	NA	NS	NS	NA
Smallmouth Bass	0.0016-0.1646	0.001-0.24	0.04	NS	0.001-0.0172	0.04[d]	NS	NS	0.24[d]
Rock Bass	NS	0.001-0.0174	0.01	0.0012-0.0252	0.0019-0.0041	0.01	0.0021-0.237	NS	0.24[d]

a = The 95% upper confidence limit on the mean (UCL) calculation includes all available data sets.
b = "NS" (no samples) indicates that the fish were not collected.
c = A 95% UCL was not available (NA) because no fish were collected.
d = The 95% UCL includes data from fish collected in 2006 or may have been calculated only with data from fish collected in 2006.

Table 9: Minimum, Maximum, and 95% Upper Confidence Limit of the mean (UCL) in parts per million (ppm) of mercury, in fish collected in 2010 and 2011 from Marshall Pond, Ceresco Impoundment, and Morrow Lake.

Fish	Levels of mercury (in ppm)								
	Marshall Pond			Ceresco Impoundment			Morrow Lake		
	2010	2011	95% UCL[a]	2010	2011	95% UCL[a]	2010	2011	95% UCL[a]
Bluegill	NS[b]	NS	NA[c]	NS	NS	NA	0.025-0.055	0.022-0.063	0.05
Carp	0.041-0.23	0.067-0.28	0.15	0.074-0.21	0.061-0.16	0.13	0.059-0.65	0.082-0.37	0.27
Largemouth Bass	NS	0.12-0.45	0.27	NS	NS	NA	NS	NS	NA
Smallmouth Bass	0.064-0.14	0.068-0.24	0.16	NS	0.064-0.38	1.0[d]	NS	NS	0.59[d]
Rock Bass	NS	0.054-0.13	0.1	0.052-0.085	0.034-0.061	0.07	0.075-0.14	NS	0.59[d]

a = The 95% upper confidence limit on the mean (UCL) calculation includes all available data sets.
b = "NS" (no samples) indicates that the fish were not collected.
c = A 95% UCL was not available (NA) because no fish were collected.
d = The 95% UCL includes data from fish collected in 2006 or may have been calculated only with data from fish collected in 2006.

MDCH issued fish consumption guidelines based on PCB and mercury levels for Kalamazoo River and Morrow Lake fish. The levels of PCBs and mercury were similar to those seen before the oil spill. Based on the levels of nickel, vanadium, and PAHs, no fish consumption guidelines are necessary for these chemicals.

- For the Kalamazoo River, in Marshall Pond, people should eat no more than 8 *MI Servings* per month (*MI Servings*/month) of rock bass; 4 *MI Servings*/month of smallmouth bass, largemouth bass less than 18 inches, or carp; and 2 *MI Servings*/month of largemouth bass greater than 18 inches. A *MI Serving* is 8 ounces for an adult (80 kilograms [kgs]) and 2-4 ounces for children (20-40 kgs). See the Eat Safe Fish Guide for more information (www.michigan.gov/eatsafefish).
- For the Kalamazoo River, from the Marshall Pond Dam to Ceresco Impoundment, people should eat no more than 8 *MI Servings*/month of rock bass greater than 8 inches; 4 *MI Servings*/month of smallmouth bass less than 18 inches; 2 *MI Servings*/month of smallmouth bass greater than 18 inches; and 1 meal/month of carp.
- Kalamazoo River from the Ceresco Dam to Morrow Dam, including Morrow Lake, people should eat no more than 16 *MI Servings*/month of bluegill; 8 *MI Servings*/month of rock bass; 6 *MI Servings*/year of smallmouth bass; and healthy adults should limit their consumption (to 1-2 *MI Servings*/year) of carp. See the Eat Safe Fish Guide for more information.

The above guidelines are from the 2014-2015 Eat Safe Fish Guide (formerly the Michigan Fish Advisory). Check the Eat Safe Fish Guide for the most current fish consumption guidelines (www.michigan.gov/eatsafefish).

Exposure Pathways Analysis

There are five things to consider when deciding if a person may be exposed to a chemical, also known as an *exposure pathway*: (1) where is the chemical coming from (source), (2) what in a person's environment has been contaminated (environmental medium), (3) is there a way a person might come into contact with the chemical (exposure point), (4) how they might come into contact with the chemical (exposure route), and (5) who might be exposed to it (exposed population). An exposure pathway is complete if it is expected or there is proof that all five elements are present. It is considered either a potential or an incomplete pathway if there is a lower probability of exposure or there is no evidence that at least one of the elements above are, have been, or will be present. Table 10 summarizes the exposure pathway for residents and visitors recreationally using the areas of the Kalamazoo River and Morrow Lake (Calhoun and Kalamazoo Counties), Michigan, impacted by the July 2010 Enbridge pipeline release of crude oil.

Table 10: Exposure pathway for residents and visitors recreationally using the areas of the Kalamazoo River and Morrow Lake (Calhoun and Kalamazoo Counties), Michigan, impacted by the July 2010 Enbridge pipeline release of heavy crude oil.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Time Frame	Exposure
Heavy crude oil (crude oil-related chemicals)	Surface water	Surface water	Incidental ingestion and dermal contact	Residents and visitors using the river and lake	Past Present Future	Incomplete[a] Completed[b] Potential[c]
Heavy crude oil (crude oil-related chemicals)	Surface water and sediment	Fish	Ingestion	Residents and visitors who eat fish	Past Present Future	Incomplete Completed Potential
Other sources or contaminated areas (non-oil-related chemicals)	Surface water	Surface water	Incidental ingestion and dermal contact	Residents and visitors using the river and lake	Past Present Future	Incomplete Completed Potential
Other sources or contaminated areas (non-oil-related chemicals)	Surface water and sediment	Fish	Ingestion	Residents and visitors who eat fish	Past Present Future	Incomplete Completed Potential

a = Incomplete indicates that all five elements of the exposure were or are not present.
b = Completed indicates that all five elements of the exposure pathway are either expected to occur or occurring.
c = Potential indicates that all five elements of the exposure pathway may have occurred in the past or may occur in the future.

People using the Kalamazoo River or Morrow Lake for recreational activities, such as canoeing, fishing, or swimming, may encounter oil sheen on the water or vegetation. Although this oil sheen may be present in a few millimeters thick layer on top of the water, very few chemicals were found in the surface water in samples collected in 2011 and 2012.

Only one analyte, benzo(a)pyrene, was detected above the surface water screening levels from samples collected between January 2011 and April 17, 2012. Benzo(a)pyrene was detected in two out of 503 surface water samples collected between May and August 2011. The average benzo(a)pyrene value is approximately equivalent to the screening level of 2 µg/L. While people may occasionally encounter benzo(a)pyrene in the water, the levels present are not expected to be harmful to people's health.

Dibenz(a,h)anthracene was not detected in any of the 631 samples collected from May to December 2011. Although 131 samples had reporting limits over the screening level of 2 µg/L, the average (2.2 µg/L) was just slightly over the screening level. Dibenz(a,h)anthracene may sometimes be present in the surface water in amounts over the screening level. People are not expected to encounter amounts that are consistently over the screening level. The amounts that could be present (those above the screening level, but below the reporting limit) are not expected to be harmful to people's health.

Higher levels of benzo(a)pyrene or dibenz(a,h)anthracene may be present in areas with oil sheen (both sheen from remaining oil from the July 2010 oil spill and sheen from other sources). In general, people should minimize their contact with oil sheen as skin contact can cause temporary skin irritation. Avoid areas with sheen, if possible. If people get sheen or tar globules on their skin, wash with soap and water as soon as possible.

Some analytes had reporting limits consistently above the surface water screening levels. These were 1,2,3-trichloropropane and trans-1,4-dichloro-2-butene. For 1,2,3-trichloropropane, all 161 surface water samples collected between May 2011 and April 17, 2012 had reporting limits over the screening level (0.07 µg/L). The reporting limit for all samples was 1 µg/L. Since this chemical is not expected to be present in the water, one-half of the reporting limit can be used to compare to the screening level. Since one-half of the reporting limit, 0.5 µg/L, is still above the screening level, 1,2,3-trichloropropane will be discussed in the "Toxicological Evaluation" section.

All 161 surface water samples, collected between May 2011 and April 17, 2012, tested for trans-1,4-dichloro-2-butene were above the screening level (0.0012 µg/L). The highest reporting limit was 5 µg/L. As half of that limit, 2.5 µg/L is still above the screening level, trans-1,4-dichloro-2-butene will be discussed in the "Toxicological Evaluation" section.

Some analytes did not have any screening levels (DRO, GRO, ORO, p-isopropyltoluene, titanium, and methyl iodide). These will be discussed in the "Analytes with No Screening Levels" section.

People fishing in the Kalamazoo River, including Marshall Pond and Ceresco Impoundment, or Morrow Lake should limit their consumption of certain fish because of mercury and PCB levels. Nickel and vanadium were not detected in any of the fish filets and only low levels of the PAHs measured were found. The levels of PAHs present in the fish filets are not a health concern and do not result in any fish consumption guidelines.

Toxicological Evaluation

No chemicals identified in the oil were present in the surface water or fish filet samples at levels that would be expected to cause more than temporary skin irritation with contact.[12]

The mercury and PCB levels present in some fish species were high enough for MDCH to issue fish consumption guidelines. Following the fish consumption guidelines will limit people's exposure to these chemicals so that no health effects will be expected for any individuals, including children. The fish consumption guidelines can be found after Table 9 (on page 21). Check www.michigan.gov/eatsafefish for the most current guidelines.

[12] Titanium and p-isopropyltoluene were detected in surface water samples, but there are no screening levels for these two analytes. They will be discussed in the "Analytes with No Screening Levels" section.

1,2,3-Trichloropropane

One hundred and sixty-one surface water samples were tested for 1,2,3-trichloropropane between May 2011 and April 17, 2012. This chemical was not detected in any of the samples, however, the reporting limit (1 µg/L, the lowest level that could accurately be measured) for all samples was over the screening level of 0.07 µg/L.

Regular swimmers would be expected to ingest about 0.38 µg[13] of 1,2,3-trichloropropane over the course of a year. This amount is lower than the amount that people may be exposed to through their diet. FDA food survey values indicate that levels between 3.53 and 6.12 part per billion (or µg/kg), with an average of 4.21ppb, were found in nine food items tested, with the highest levels in sandwich cookies (Heikes et al. 1995). The total amount a person may ingest over 150 days swimming is about equal to 2 servings of sandwich cookies.[14] People are expected to be exposed to this chemical through foods, drinking water, and outside air (NLM 2009c).The levels that could be present in the water are not expected to add much to people's typical exposure. People's health would not be harmed from this exposure.[15]

trans-1,4-Dichloro-2-butene

This chemical, trans-1,4-dichloro-2-butene, was measured in 161 surface water samples collected between May 2011 and April 17, 2012. It was not detected in any of the samples. The reporting limit (the lowest levels that could accurately be measured) was 1 µg/L for 152 of the samples and 5 µg/L for nine of the samples. Both of these reporting limits were over the screening level of 0.0012 µg/L.[16] This screening level is based on inhalation of the chemical. If this chemical is even present in the surface water, it is expected to volatilize and be degraded in the air within about a week. It will also degrade in the water within a few days (NLM 2009b). Because it was not detected, it degrades fairly quickly in the air and water, and no locations along the river seem to be contaminated with this chemical,[17] people are expected to be exposed to very little or no trans-1,4-dichloro-2-butene in surface water. The only exposure expected is to the background levels that may be present here and in other similar locations. This exposure is not expected to harm people's health.

[13] As this chemical is not expected to be present, one-half of the reporting limit (0.5 µg/L) was used to calculate this value. Regular swimmers would be expected to accidently swallow about 0.75 L of water over 150 days. This would result in swallowing a maximum of 0.38 µg of 1,2,3-trichloropropane over those 150 days. The amount that would be dermally absorbed would add only an insignificant amount of 1,2,3-trichloropropane to the amount ingested (less than 0.01 µg).

[14] If a serving of sandwich cookies is 34 grams (1.2 ounces), the amount of 1,2,3-trichloropropane is 0.204 µg/serving (6.12 µg/30 servings in a kilogram [kg]). Two servings is approximately 0.4 µg of 1,2,3-trichloropropane.

[15] Adults and children would ingest less (0.000032-0.00025 µg/kg-day) than the reference dose of 4 µg/kg-day from accidently swallowing river or lake water while swimming. If people did swallow this amount, an estimated cancer risk would be less than 1 in 100,000, which means out of 100,000 people exposed less than one additional person could develop cancer.

[16] As trans-1,4-dichloro-2-butene is not expected to be present in the surface water, one-half of the reporting limit would be 0.5 or 2.5 µg/L. Both are above the screening level of 0.0012 µg/L.

[17] This information is from the list of chemicals found in nearby Part 201 sites (Enbridge 2010).

Analytes with No Screening Levels

Oil-related Chemicals

DRO (C10-C20)

DRO (diesel range organics) are chemicals with 10 to 20 carbons in the structure. This is a generic designation for many specific chemicals present in petroleum products and may measure chemicals that are from plant or bacterial sources. Of the 912 samples collected in 2011, DRO was detected in four samples (less than 0.5% of the total samples). The maximum level detected was 40,000 µg/L. DRO data are most useful in identifying whether petroleum products are present in the samples, not to assess any potential health concerns. The results from the surface water samples indicate that chemicals that can be measured with this analysis were very rarely detected in surface water in 2011.

GRO (C6-C10)

GRO (gasoline range organics) are chemicals with six to ten carbons in the structure. Similar to DRO, this is a generic designation. GRO was not detected in any of the 879 surface water samples analyzed and the reporting limit was 200 µg/L. GRO data are most useful in identifying whether petroleum products are present in the samples, not to assess any potential health concerns. The results from the surface water samples do not indicate that GRO were present in surface water, above 200 µg/L, in 2011.

ORO (C20-C34)

ORO (oil range organics) are chemicals with 20 to 34 carbons in the structure. As with DRO and GRO, any hydrocarbon with the correct number of carbons will be measured, which include chemicals from plant or bacterial sources. OROs were detected in 79 out of the 748 surface water samples analyzed (about 10% of the total samples). The detections ranged from 48 to 170,000 µg/L. ORO data are most useful in identifying whether petroleum products are present in the samples, not to assess any potential health concerns. The results from the surface water samples indicate that petroleum products, or chemicals from plant or bacterial sources, may have been present in surface water in 2011.

p-Isopropyltoluene

Over 1,000 surface water samples (1,026) were analyzed for p-isopropyltoluene, also called p-cymene, from January 2011 to April 17, 2012. This chemical was only detected in two, at 0.41 and 9.5 µg/L, of the samples.[18] The U.S. Food and Drug Administration (FDA) allows this chemical to be added to foods as a flavoring (NLM 2010a). Exposure to the levels present in surface water is not a health concern.

Titanium

People ingest titanium in food, such as milled grains, butter, corn oil, and lettuce (IPCS 1982). There is not enough information available on titanium to determine levels that could cause harm to people's health. However, titanium is used in a variety of medical devices, such as knee or hip joint replacements and dental implants and there is no evidence of toxicity from these implants

[18] These two samples represent 0.2% of the total samples tested from January 2011 to April 17, 2012.

(IPCS 1982). One form of titanium, titanium dioxide, is FDA-approved for use as a color additive in food (NLM 2009a). Titanium was tested in 1,182 surface water samples collected between January and August 2011. The range of titanium detected in the samples was 0.55 to 49 µg/L. People's bodies will not absorb a majority of the titanium in the water. The highest amount that regular swimmers may accidently drink totals 40 µg of titanium.[19] This total (for the entire year) would only be about 10% of a person's daily titanium intake from the average amount in the typical U.S. diet (NLM 2002). People's exposure to titanium from accidental swallows of water is not expected to add much to the typical daily exposure and is not expected to harm people's health.

Non-oil-related Chemicals

Methyl iodide

One hundred and sixty-one surface water samples were tested for methyl iodide between May 2011 and April 17, 2012. This chemical was not detected in any of the samples. The reporting limit (the lowest level that could accurately be measured) was 1 µg/L.

People are exposed to small amounts of methyl iodide in the air and in ocean seafood (NLM 2010b). Based on the reporting limits for the surface water samples, the maximum amount of methyl iodide that a person would accidently swallow over the course of 150 days is 0.38 µg.[20] This is about ten times lower than the amount that a person could have from one meal of ocean fish.[21] The amount of methyl iodide that a person could accidently swallow would not harm people's health.

Community Health Concerns

Individuals have concerns about watering their gardens and/or lawns with water from the river. These concerns are, in part, due to on-going oil recovery activities, such as surface boom on the river or submerged oil removal. People are primarily concerned about chemicals dissolved in the water, but are also concerned about sheen or tar globules being sprayed onto the edible and non-edible parts of plants (Steve Noble, MDEQ, personal communication 2012). People's health will not be harmed from direct contact with chemicals dissolved in the water. Any sheen or tar globules in the water may cause temporary skin irritation while people are irrigating.

The chemicals present, or possibly present, in the water may accumulate in the plants. However, this accumulation is smaller than the amount of the chemicals that would be expected to remain on the surface of the plant from splashed soil/water droplets (Samsoe-Petersen et al. 2002, Fismes et al. 2002). The potential oil sheen or tar globules remaining from being sprayed on gardens could irritate people's skin if they are tending the garden without gloves. Produce with visible oil sheen or tar globules should not be eaten. Individuals may want to consider alternate

[19] This is if people swim for 0.1 hours daily for 150 days (15 hours) and accidently swallow 0.05 L of water per hour of swimming (0.75 L of water). If the water always had 49 µg titanium/L, people would swallow 0.040 µg of titanium over the 150 days.

[20] Since the chemical was never detected and is not expected to be present, one-half of the reporting limit was used (0.5 µg/L). A person swimming each day for 150 days would accidently swallow 0.75 L of river or lake water. People would swallow approximately 0.38 µg of methyl iodide over those 150 days (0.5 µg/L x 0.75 L = 0.38µg).

[21] The median level of methyl iodide in five species of fish was 17 µg/kg (NLM 2010b). From one 8 ounce meal (0.227 kg), people would ingest 3.9 µg of methyl iodide (17 µg/kg x 0.227 kg = 3.9 µg).

watering methods, such as drip irrigation (root vegetables may still have this material on the surface) or an alternate water source.

Children's Health Considerations

Children do more hand-to-mouth behaviors than adults, which may increase the exposure to any chemicals present. Children may be at greater risk than adults when exposed to certain hazardous substances. A child's lower body weight and higher intake rate result in a greater dose of hazardous chemicals compared to their weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children may be damaged. Screening levels used in this PHA are protective for children as well as adults.

Oil sheen or tar globules may be attractive for children to touch. This could result in temporary skin irritation. If children get oil sheen or tar globules on their skin, it should be washed off as soon as possible with soap and water. Accidently swallowing sheen or a tar globule may cause gastrointestinal upset.

Conclusions

Chemical levels found in surface water are not expected to cause long-term harm to people's health. People may have temporary health effects, such as skin irritation, from contact with oil sheen or tar globules in the water. Oil-related and non-oil related chemicals were measured in the surface water. Only a very few of these chemicals were detected above health-protective screening levels in surface water samples. These chemicals were mostly polycyclic aromatic hydrocarbons. People are not expected to be exposed to chemical levels that would cause long-term health concerns. However, if people have contact with these chemicals or the oil sheen and globules in the river, they may develop temporary health effects, such as skin irritation.

Oil-related chemical levels found in fish from the Kalamazoo River and Morrow Lake will not harm people's health. However, MDCH has issued fish consumption guidelines because of mercury and polychlorinated biphenyls (PCBs) levels found in the filets. Fish were collected from Marshall Pond, Ceresco Impoundment, and Morrow Lake. Marshall Pond is upstream of the oil spill. Chemical levels in Marshall Pond fish filets were similar to levels found in Ceresco Impoundment and Morrow Lake fish. Two chemicals not related to the oil spill, mercury and PCBs, were found in the fish filets. MDCH recommends that people limit the amount of certain Kalamazoo River and Morrow Lake fish they eat. (Guidelines listed in this PHA are listed in the 2014-2015 Eat Safe Fish Guide.) Current guidelines can be found at: www.michigan.gov/eatsafefish.

Recommendations

- Avoid contact with oil sheen, if possible. If people do have direct contact with the sheen, wash skin with soap and water.

- Follow the fish consumption guidelines in the Eat Safe Fish Guide (www.michigan.gov/eatsafefish).

Public Health Action Plan

- MDCH will remain available as needed for health concerns related to the Kalamazoo River/Enbridge Spill.

- MDCH will update the Eat Safe Fish Guide as needed.

If individuals want additional information or have health concerns, please contact MDCH's Division of Environmental Health at 1-800-648-6942.

Report Preparation

This Public Health Assessment was prepared by the Michigan Department of Community Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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for that chemical was calculated. If the 95% UCL was below the screening level, no further evaluation was necessary. The 95% UCL was used because waterbody-specific fish guidelines are set based on the 95% UCL for a specific chemical.

Table B-2, B-3, and B-4 presents the PAH, nickel, and vanadium levels in Marshall Pond, Ceresco Impoundment, and Morrow Lake, respectively. Benzo(a)pyrene (BaP) equivalent values are included in the tables. The BaP equivalent value is the amount of BaP and PAHs that act in the same manner in people's bodies. The other PAHs are benzo(b)fluoranthene, benzo(a)anthracene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The concentration of these PAHs present in the fish filet are multiplied by a relative potency factor (EPA 1993). The BaP equivalent value is the sum of all seven values (concentration x relative potency factor).

Table B-2: Range (minimum and maximum in parts per billion [ppb]) of polycyclic aromatic hydrocarbons (PAHs), nickel, and vanadium in fish collected in 2010 and 2011 from Marshall Pond.

Chemical	Collected in 2010		Collected in 2011			
	Carp	Smallmouth Bass	Carp	Largemouth Bass	Rock Bass	Smallmouth Bass
1-Methylnaphthalene	0.31-2.23	0.33-0.53	0.48-2.05	0.5-1.83	0.87-1.64	1.08-2.63
1-Methylphenanthrene	0.2 (DL)[a]-0.54	0.2 (DL)	0.2 (DL)-2.15	0.48-1	0.26-1.36	0.27-0.67
2,6-Dimethylnaphthalene	0.57-2.01	0.65-0.98	0.2 (DL)	0.29-0.61	0.25-0.4	0.35-0.9
2-Methylnaphthalene	0.2 (DL)-2.63	0.28-0.61	0.36-1.8	0.34-1.01	0.53-1.09	0.57-1.46
Acenaphthene	0.24-14.91	0.85-2.64	0.94-7.04	0.54-1.07	0.34-0.95	0.63-2.18
Acenaphthylene	0.2 (DL)-0.73	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Anthracene	0.2 (DL)	0.26-0.66	0.2 (DL)-0.74	0.2 (DL)-0.33	0.2 (DL)-2.12	0.2 (DL)-0.54
Benzo(a)pyrene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.81	0.2 (DL)
Benzo(b)fluoranthene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.85	0.2 (DL)
Benzo(a)anthracene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-1.68	0.2 (DL)
Benzo(e)pyrene	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.92	0.2 (DL)
Benzo(g,h,i)perylene	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.35	0.2 (DL)
Benzo(k)fluoranthene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Chrysene[b]	0.2 (DL)-0.31	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-1.74	0.2 (DL)
Dibenz(a,h)anthracene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Fluoranthene	0.2 (DL)-4.71	0.48-1.36	0.37-4.21	0.4-0.83	0.5-8.19	0.62-1.22
Fluorene	0.26-8.27	0.76-1.89	0.48-4.19	0.47-0.85	0.33-1.19	0.68-1.59

Table B-2 continued						
Chemical	Collected in 2010		Collected in 2011			
	Carp	Smallmouth Bass	Carp	Largemouth Bass	Rock Bass	Smallmouth Bass
Indeno(1,2,3-cd)pyrene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Naphthalene	0.84-4.86	1.02-1.65	1.1-3.28	0.97-2.92	1.48-2.19	1.41-2.83
Phenanthrene	0.4-13.26	1.53-3.84	1.12-7.72	1.64-2.88	0.86-8.99	2.05-4.67
Pyrene	0.2 (DL)-2.16	0.2 (DL)-0.34	0.2 (DL)-1.86	0.2 (DL)-0.21	0.61-5.74	0.38-0.6
BaP equivalents[c]	0.46-0.46	0.46-0.46	0.46-0.46	0.46-0.46	0.20-1.26	0.46-0.46
Nickel	0.6 (DL)	0.6 (DL)	0.6 (DL)	0.6 (DL)	0.6 (DL)	0.6 (DL)
Vanadium	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)

a = DL indicated detection limit
b = PAHs included in the BaP equivalent values
c = Sum of chemical relative to benzo(a)pyrene toxicity indicated with "b" note. (BaP equivalent = sum of [concentration* relative potency]. Relative potencies were from EPA [1993].)

Only the maximum level of BaP equivalents was over the preliminary screening level for rock bass, collected in 2011, from Marshall Pond. However, the 95% UCL (0.7 ppb) was not over the screening level of 0.9 ppb. No further evaluation of Marshall Pond fish was needed.

Table B-3: Range (minimum and maximum in parts per billion [ppb]) of polycyclic aromatic hydrocarbons (PAHs), nickel, and vanadium in fish collected in 2010 and 2011 from Ceresco Impoundment.

Chemical	Collected in 2010		Collected in 2011		
	Carp	Rock Bass	Carp	Rock Bass	Smallmouth Bass
1-Methylnaphthalene	0.59-12.8	0.87-7.5	1.15-3.13	1.22-2.26	1.15-2.73
1-Methylphenanthrene	0.2 (DL)[a]-0.81	0.2 (DL)	0.2 (DL)	0.21-2.41	0.2 (DL)-1.24
2,6-Dimethylnaphthalene	0.63-1.97	0.62-1.5	NA	0.89-0.89	0.44-0.95
2-Methylnaphthalene	0.6-8.1	0.45-3.91	0.96-3.14	0.79-1.47	0.84-1.55
Acenaphthene	1-8.35	0.33-0.84	1.45-8.02	0.8-1.12	0.61-1.83
Acenaphthylene	0.2 (DL)-1.7	0.2 (DL)-0.26	NA	0.2 (DL)	0.2 (DL)
Anthracene	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.23	0.2 (DL)-0.36
Benzo(a)pyrene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.36	0.2 (DL)	0.2 (DL)
Benzo(b)fluoranthene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Benzo(a)anthracene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Benzo(e)pyrene	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.4	0.2 (DL)	0.2 (DL)
Benzo(g,h,i)perylene	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.31	0.2 (DL)	0.2 (DL)
Benzo(k)fluoranthene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Chrysene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.34	0.2 (DL)
Dibenz(a,h)anthracene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.29	0.2 (DL)	0.2 (DL)
Fluoranthene	0.3-1.49	0.2 (DL)-0.37	0.75-3.42	0.52-1.18	0.41-2.25
Fluorene	0.66-3.41	0.41-0.64	1.12-3.31	0.63-0.96	0.57-1.55
Indeno(1,2,3-cd)pyrene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Naphthalene	1.85-16.1	1.73-7.3	2.24-6.1	3.22-3.83	3.09-6.96
Phenanthrene	0.59-3.07	0.43-0.78	1.14-4.48	1.74-3.42	1.35-4.94
Pyrene	0.2 (DL)-0.81	0.2 (DL)	0.46-1.77	0.32-0.7	0.21-0.92
BaP equivalents[c]	0.46-0.46	0.46-0.46	0.46-0.67	0.46-0.46	0.46-0.46
Nickel	600 (DL)	600 (DL)	600 (DL)	600 (DL)	600 (DL)
Vanadium	200 (DL)	200 (DL)	200 (DL)	200 (DL)	200 (DL)

a = DL indicated detection limit

b = PAHs included in the BaP equivalent values

c = Sum of chemical relative to benzo(a)pyrene toxicity indicated with "b" note. (BaP equivalent = sum of [$concentration_x$* relative $potency_x$]. Relative potencies were from EPA [1993].)

None of the maximum chemical levels measured in fish filets collected from Ceresco Impoundment were over the preliminary screening levels. No further evaluation is needed.

Table B-4: Range (minimum and maximum in parts per billion [ppb]) of polycyclic aromatic hydrocarbons (PAHs), nickel, and vanadium in fish collected in 2010 and 2011 from Morrow Lake.

Chemical	Collected in 2010			Collected in 2011	
	Bluegill	Carp	Rock Bass	Bluegill	Carp
1-Methylnaphthalene	0.56-1.2	1.4-2.91	0.84-1.55	1.11-1.74	0.63-1.95
1-Methylphenanthrene	0.2 (DL)-0.37	0.2 (DL)-0.82	0.2 (DL)-0.85	0.2 (DL)	0.2 (DL)
2,6-Dimethylnaphthalene	0.53-1.3	0.2 (DL)-0.72	0.2 (DL)-0.78	0.48-0.48	0.53-0.53
2-Methylnaphthalene	0.34-0.75	0.82-2.39	0.41-0.79	0.6-0.94	0.38-1.49
Acenaphthene	0.2 (DL)	0.2 (DL)-0.21	0.2 (DL)	0.33-0.69	0.37-2.26
Acenaphthylene	0.2 (DL)	0.2 (DL)-0.23	0.2 (DL)	0.2 (DL)	0.2 (DL)
Anthracene	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Benzo(a)pyrene[b]	0.2 (DL)-0.48	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Benzo(b)fluoranthene[b]	0.2 (DL)-0.55	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Benzo(a)anthracene[b]	0.2 (DL)-0.38	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Benzo(e)pyrene	0.2 (DL)-0.56	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.25	0.2 (DL)
Benzo(g,h,i)perylene	0.2 (DL)-0.31	0.2 (DL)	0.2 (DL)	0.2 (DL)-0.4	0.2 (DL)
Benzo(k)fluoranthene[b]	0.2 (DL)-0.25	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Chrysene[b]	0.2 (DL)-0.7	0.2 (DL)-0.44	0.2 (DL)	0.2 (DL)	0.2 (DL)
Dibenz(a,h)anthracene[b]	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Fluoranthene	0.2 (DL)-1.93	0.2 (DL)-2.16	0.2 (DL)-0.4	0.76-1.3	0.58-2.84
Fluorene	0.36-0.36	0.2 (DL)-0.25	0.2 (DL)	0.47-0.7	NA
Indeno(1,2,3-cd)pyrene[b]	0.2 (DL)-0.36	0.2 (DL)	0.2 (DL)	0.2 (DL)	0.2 (DL)
Naphthalene	1.87-3.23	2.78-6.58	1.77-3.37	1.7-3	0.96-2.74
Phenanthrene	0.38-1.65	0.31-1.38	0.34-0.92	1.28-2.02	0.81-2.85
Pyrene	0.2-1.28	0.2 (DL)-0.78	0.2 (DL)	0.52-0.52	0.51-1.46
BaP equivalents[c]	0.46-0.81	0.46-0.46	0.46-0.46	0.24-0.46	0.46-0.46
Nickel	600 (DL)	600 (DL)	600 (DL)	600 (DL)	600 (DL)
Vanadium	200 (DL)	200 (DL)	200 (DL)	200 (DL)	200 (DL)

a = DL indicated detection limit
b = PAHs included in the BaP equivalent values
c = Sum of chemical relative to benzo(a)pyrene toxicity indicated with "b" note. (BaP equivalent = sum of [concentration* relative potency]. Relative potencies were from EPA [1993].)

None of the maximum chemical levels measured in fish filets collected from Morrow Lake were over the preliminary screening levels. No further evaluation is needed.

Tables B-5 and B-6 present the PCB and mercury, respectively, in fish collected from Marshall Pond, Ceresco Impoundment, and Morrow Lake. MDCH issued fish consumption guidelines for certain fish species due to the presence of PCBs and mercury in the fish filets. The fish consumption guidelines are listed below the tables.

Table B-5: Minimum, Maximum, and 95% Upper Confidence Limit of the mean (UCL) in parts per million (ppm) of polychlorinated biphenyls (PCBs), in fish collected in 2010 and 2011 from Marshall Pond, Ceresco Impoundment, and Morrow Lake.

Fish	Levels of PCBs (in ppm)								
	Marshall Pond			Ceresco Impoundment			Morrow Lake		
	2010	2011	95% UCL[a]	2010	2011	95% UCL	2010	2011	95% UCL[a]
Bluegill	NS[b]	NS	NA[c]	NS	NS	NA	0.0054-0.0162	0.0019-0.0074	0.01
Carp	0.001-0.0908	0.0031-0.0826	0.04	0.0139-0.2448	0.0035-0.066	0.12	0.0519-0.3041	0.0697-0.8292	0.55
Largemouth Bass	NS	0.001-0.0126	0.01	NS	NS	NA	NS	NS	NA
Smallmouth Bass	0.0016-0.1646	0.001-0.24	0.04	NS	0.001-0.0172	0.04[d]	NS	NS	0.24[d]
Rock Bass	NS	0.001-0.0174	0.01	0.0012-0.0252	0.0019-0.0041	0.01	0.0021-0.237	NS	0.24[d]

a = The 95% upper confidence limit on the mean (UCL) calculation includes all available data sets.
b = No samples were collected (NS).
c = The 95% UCL could not be calculated and was not available (NA).
d = These values include fish collected in 2006 or may only be from fish collected in 2006.

Table B-6: Minimum, Maximum, and 95% Upper Confidence Limit of the mean (UCL) in parts per million (ppm) of mercury, in fish collected in 2010 and 2011 from Marshall Pond, Ceresco Impoundment, and Morrow Lake.

Fish	Levels of mercury (in ppm)								
	Marshall Pond			Ceresco Impoundment			Morrow Lake		
	2010	2011	95% UCL[a]	2010	2011	95% UCL	2010	2011	95% UCL[a]
Bluegill	NS[b]	NS	NA[c]	NS	NS	NA	0.025-0.055	0.022-0.063	0.05
Carp	0.041-0.23	0.067-0.28	0.15	0.074-0.21	0.061-0.16	0.13	0.059-0.65	0.082-0.37	0.27
Largemouth Bass	NS	0.12-0.45	0.27	NS	NS	NA	NS	NS	NA
Smallmouth Bass	0.064-0.14	0.068-0.24	0.16	NS	0.064-0.38	1.0[d]	NS	NS	0.59[d]
Rock Bass	NS	0.054-0.13	0.1	0.052-0.085	0.034-0.061	0.07	0.075-0.14	NS	0.59[d]

a = The 95% upper confidence limit on the mean (UCL) calculation includes all available data sets.
b = No samples were collected (NS).
c = The 95% UCL could not be calculated and was not available (NA).
d = These values include fish collected in 2006 or may only be from fish collected in 2006.

Recommendations for fish consumption guidelines based on PCB and mercury levels in Kalamazoo River and Morrow Lake fish are below (2014-2015 Eat Safe Fish Guide [formerly the Michigan Fish Advisory]). Fish consumption guidelines are not needed for nickel, vanadium, and PAHs.

- For the Kalamazoo River, in Marshall Pond, people should eat no more than 8 *MI Servings* per month (*MI Servings*/month) of rock bass; 4 *MI Servings*/month of smallmouth bass, largemouth bass less than 18 inches, or carp; and 2 *MI Servings*/month of largemouth bass greater than 18 inches. The typical meal size is 8 ounces for adults and 2-4 ounces for children. See the Eat Safe Fish Guide for more information (www.michigan.gov/eatsafefish).
- For the Kalamazoo River, from the Marshall Pond Dam to Ceresco Impoundment, people should eat no more than 8 *MI Servings*/month of rock bass greater than 8 inches; 4 *MI Servings*/month of smallmouth bass less than 18 inches; 2 *MI Servings*/month of smallmouth bass greater than 18 inches; and 1 meal/month of carp.
- Kalamazoo River from the Ceresco Dam to Morrow Dam, including Morrow Lake, people should eat no more than 16 *MI Servings*/month of bluegill; 8 *MI Servings*/month of rock bass; 6 *MI Servings*/year of smallmouth bass; and healthy adults should limit their consumption (to 1-2 *MI Servings* per year) of carp. See the Eat Safe Fish Guide for more information.

Check the Eat Safe Fish Guide for the most current fish guidelines (www.michigan.gov/eatsafefish).