# Health Consultation

FORMER PETOSKEY PETROLANE

PETOSKEY, EMMET COUNTY, MICHIGAN

**Prepared by the**
**Michigan Department of Community Health**

DECEMBER 2, 2009

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

**Health Consultation: A Note of Explanation**

A health consultation is a verbal or written response from ATSDR or ATSDR's Cooperative Agreement Partners 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 or 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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# HEALTH CONSULTATION

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## Acronyms and Abbreviations

| | |
|---|---|
| µg | microgram |
| τ ("tau") | lag time |
| ADAF | age-dependent adjustment factor |
| $AE_d$ | dermal absorption efficiency |
| $AE_i$ | ingestion absorption efficiency |
| AF | soil adherence factor |
| $AT_c$ | averaging time for carcinogens |
| $AT_{nc}$ | averaging time for noncarcinogens |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| B | ratio of the stratum corneum's $K_p$ to that of the viable epidermis |
| bgs | below surface grade |
| BW | body weight |
| CAS | Chemical Abstract Services |
| CF | conversion factor |
| cm | centimeter |
| DCC | Direct Contact Criteria |
| DF | age-adjusted soil dermal factor |
| $D_{sc}$ | chemical-specific diffusivity across the stratum corneum |
| ED | exposure duration |
| $EF_d$ | dermal exposure frequency |
| $EF_i$ | ingestion exposure frequency |
| EPA | U.S. Environmental Protection Agency |
| ET | exposure time |
| EV | number of events per day |
| GCC | Groundwater Contact Criteria |
| GSI | Groundwater Surface Water Interface |
| HDNM | Health Department of Northwest Michigan |
| HI | hazard index |
| HQ | hazard quotient |
| IEUBK | Integrated Exposure Uptake Biokinetic (model for lead) |
| IF | age-adjusted soil ingestion factor |
| IR | ingestion rate |
| $I_{sc}$ | thickness of the stratum corneum |
| kg | kilogram |
| $K_{ow}$ | octanol-water coefficient |
| $K_p$ | permeability coefficient |
| MDCH | Michigan Department of Community Health |
| MDEQ | Michigan Department of Environmental Quality |
| mg | milligram |
| MW | molecular weight |
| PAH | polycyclic aromatic hydrocarbon |
| PNA | polynuclear aromatic compound |
| ppb | parts per billion |
| ppm | parts per million |

| | |
|---|---|
| RfD | Reference Dose |
| RI | Remedial Investigation |
| RSC | relative source contribution |
| SA | skin surface area |
| SF | cancer slope factor |
| SP | skin penetration per event |
| t* | time to reach steady-state |
| THQ | target hazard quotient |
| TR | target risk level |
| VOC | volatile organic compound |

## Summary

The Health Department of Northwest Michigan (HDNM) requested that the Michigan Department of Community Health (MDCH) conduct a public health evaluation at a former manufactured gas plant in Petoskey, Michigan. The local health agency was concerned about contact with contaminated sediments, uncharacterized surface and/or pore water, and the potential presence of mercury in groundwater. The site has been converted into a public park and beach, and is adjacent to a harbor connected to Little Traverse Bay in Lake Michigan.

MDCH has reached four conclusions in this health consultation report:

1. *Contact with contaminated sediments at the site is not expected to cause harm.* Benzo(a)pyrene is the only chemical in the sediment that exceeds the State of Michigan regulatory standard for daily contact with soil. Although the amount of benzo(a)pyrene also exceeds the screening level calculated for intermittent exposure, the location of the single exceedance is in an area that people are not expected to use for wading or swimming. Therefore, contact with the sediment in that area is not expected.

   Next Steps: No additional steps are needed by public health agencies to address this conclusion.

2. *Contact with chemicals that may be entering the pore water or surface water at the site is not expected to cause harm.* It is not necessary to sample this water for chemical contaminants.

   Next Steps: No additional steps are needed by public health agencies to address this conclusion.

3. *The low-level mercury sampling results suggest that groundwater containing mercury may be venting to surface water at the site.* MDCH recommends that people follow the advice in the Michigan Family Fish Consumption Guide.

   Next Steps: MDCH will continue to issue, and update as needed, the Family Fish Consumption Guide, based on fish contaminant data collected by MDEQ.

4. *There is potential for bacterial contamination at this site.* Geese have been observed using the area. Their droppings can pose a health hazard directly or through contamination of surface water. Additionally, the nearby marina may be a source of bacterial loads from sewage discharge from boats.

   Next Steps: The HDNM should sample beach surface water to help protect the health of users of the park from unacceptable bacterial contamination.

## Purpose and Health Issues

The purpose of this health consultation is to answer questions posed by HDNM regarding the former Petoskey Petrolane site in Petoskey, Emmet County, Michigan (Figure 1). The site is a former manufactured gas plant and has contamination associated with coal tar: volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and metals. A remedial investigation (RI) of the site included characterization of on-shore surficial and subsurface soils, off-shore sediments, and groundwater. On May 12, 2009, the HDNM asked MDCH for a public-health opinion on the following matters:

► Exposure to off-shore sediments. One sediment sample contained benzo(a)pyrene at a concentration exceeding the state criterion addressing direct, long-term contact with soil.

► Exposure to as-yet uncharacterized surface or pore water. According to the HDNM, the park and beach are used heavily during the summer and fishermen fishing the mouth of the Bear River will wade there.

► Exposure to mercury in the groundwater via consumption of contaminated fish.

MDCH conducted this health consultation for the federal Agency for Toxic Substances and Disease Registry (ATSDR) under a cooperative agreement. ATSDR conducts public health activities (assessments/consultations, advisories, education) at sites of environmental contamination and concern. ATSDR is primarily an advisory agency. Therefore, its reports usually identify what actions are appropriate to be undertaken by the regulatory agency overseeing the site, other responsible parties, or the research or education divisions of ATSDR. As such, ATSDR recommendations may not encompass all types of federal and state requirements from a regulatory perspective. The purpose of a health consultation is not to evaluate or confirm regulatory compliance but to determine if any potentially harmful exposures are occurring or may occur in the future.

## Background

The Petoskey Petrolane site is a former manufactured gas plant that operated from the late 1800s to the early-to-mid 1900s. It is at the western end of Bayfront Park, bounded by Little Traverse Bay and Lake Michigan to the north, Bear River to the east, Water Street to the south, and Wachtel Avenue to the west (Figure 1). The site is currently used as a public park and beach (Figure 2). The Petoskey marina is across from the beach, with the closest dock about 30 to 45 feet from the shore (Figure 3). The swimming area is not roped off from the rest of the harbor, but there are shallow-water markers (visible in Figure 2) to deter boaters from steering into the swimming area. The Bear River empties into the harbor near the beach (Figure 4) and is used by fishermen (S. Kendzierski, HDNM, personal communication, 2009).

In 1991, the city of Petoskey unearthed coal tar during excavation of sediment retention basins for Bear River dredging. The city installed a clay cap over the site to prevent volatilization of the contaminants to the surface so the property could be used as a city park (AECOM 2009).

Figure 1. Former Petoskey Petrolane Site, Emmet County, Michigan

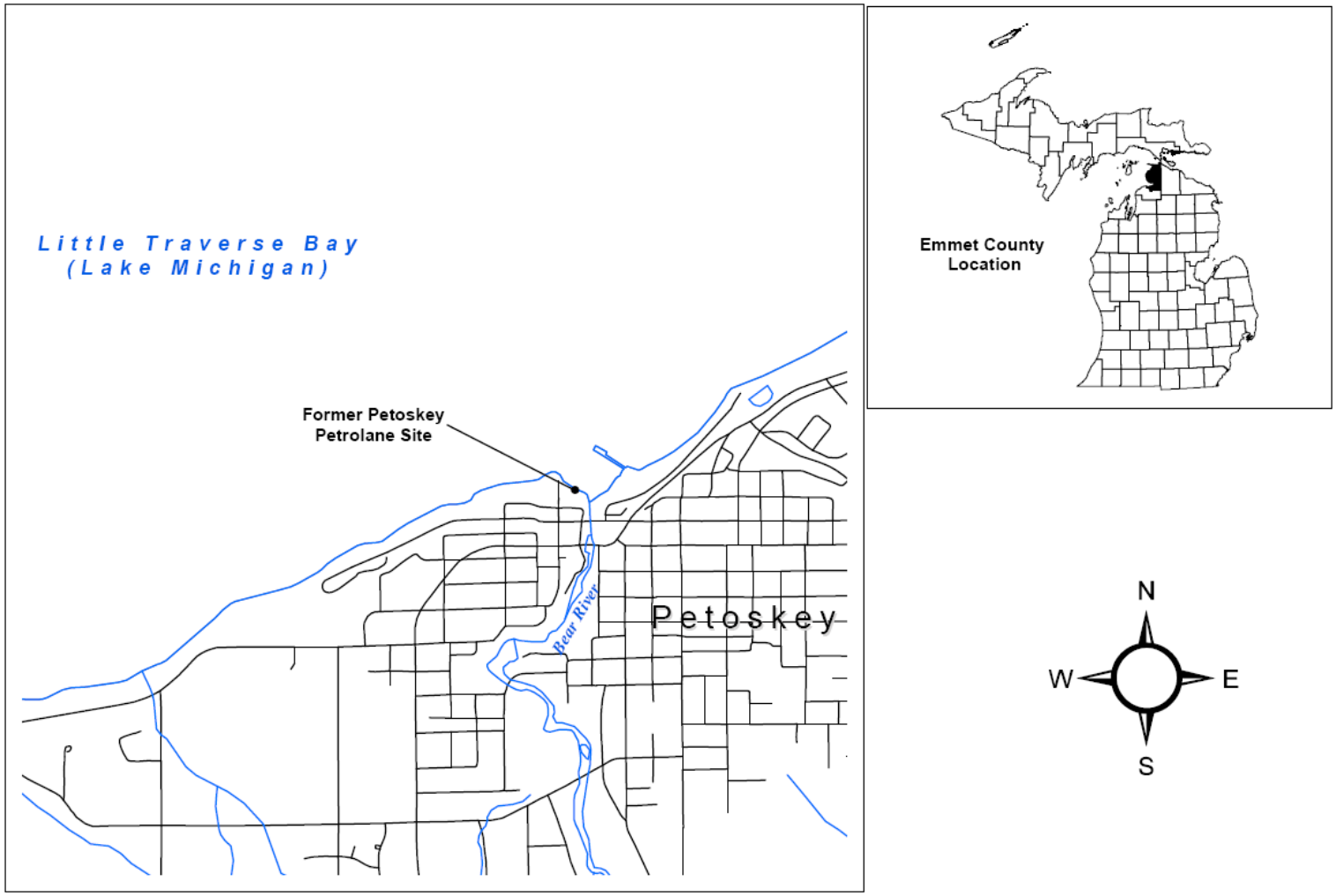


Figure 2. View of public park and beach at the Former Petoskey Petrolane site (Emmet County, Michigan), looking northwest. Lake Michigan is beyond breakwall. Shallow-water markers are visible to the right of center of the picture. A flock of Canada geese is swimming in the water at about the center of the picture.

Figure 3. Pier across from the beach at the Former Petoskey Petrolane site (Emmet County, Michigan), looking east. Bear River enters from the right.

Figure 4. Bear River entering Little Traverse Bay at the Former Petoskey Petrolane site (Emmet County, Michigan).

A remedial investigation in 1996 indicated pockets of coal tar about 10 feet below ground surface (bgs), which was beneath the water table at that depth. Groundwater samples taken from monitoring wells within 100 feet of the shoreline revealed concentrations of VOCs, PAHs, and metals exceeding state groundwater criteria protective of surface water. In 1997 and 1998, MDEQ removed contaminated soil (to a depth of 12-19 feet bgs) and treated contaminated groundwater generated during excavation activities. This was an "interim response action" (AECOM 2009), intended to address imminent hazards, not a full clean-up.

Follow-up monitoring of the site led to a second removal in 2001, due to receding lake levels exposing contaminated sediments. Soil was excavated to one to two feet below the water table. MDEQ advanced additional soil borings in 2004 due to coal tar appearing in one monitoring well. This investigation revealed coal tar contamination in the soil from a depth of about two feet bgs in the beach area to an unknown depth southwest of the 2001 excavation area (along the north-northeast boundary of the 1998 excavation; Figure 5; AECOM 2009).

MDEQ hired AECOM, Inc. to conduct the most recent RI, the results of which are discussed in the *Environmental Contamination* section below.

## Discussion

Environmental Contamination

### *Remedial Investigation*

AECOM, Inc. conducted an RI at the Petoskey Petrolane site in 2008. The work included sediment sampling using a Ponar sampling device, soil and groundwater sampling using a Geoprobe® device, installation of and sampling from monitoring wells, and bedrock assessment (determining the underlying geology). Environmental samples were analyzed for the presence of VOCs, PAHs, "Michigan 10" metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc), ammonia, cyanide, and nitrates-nitrites combined. Figure 6 shows the sampling locations.

AECOM, Inc. compared sediment results to the MDEQ Part 201 Residential/-Commercial I Direct Contact Criteria (DCC), which address long-term skin contact with and swallowing of contaminated soil, and to several ecological screening levels. Soil results were compared to the DCC and the Groundwater Surface Water Interface (GSI) Protection Criteria, which address contaminated soils leaching to groundwater that vents to surface water. Groundwater results from the Geoprobe® borings and monitoring wells were compared to the GSI criteria, which address contaminated groundwater venting to surface water, and the Groundwater Contact Criteria (GCC), which address contact with groundwater in subsurface excavations (such as utility tunnels or construction sites). Only the results for sediment and groundwater are discussed further in this document.

Because the generic DCC are applicable only to soils, it is not appropriate to compare sediment contaminant levels to these criteria. Also, the DCC considers daily contact with soil whereas, at the Petoskey Petrolane site, contact with sediments would be intermittent. Inputs used to derive the DCC can be altered to obtain an informal screening level to address both the sediment issue and exposure parameters (State of Michigan 2002a, b). MDCH derived screening levels to

Figure 5. Schematic of Former Petoskey Petrolane site (Emmet County, Michigan) showing areas previously excavated and current approximate extent of coal tar.

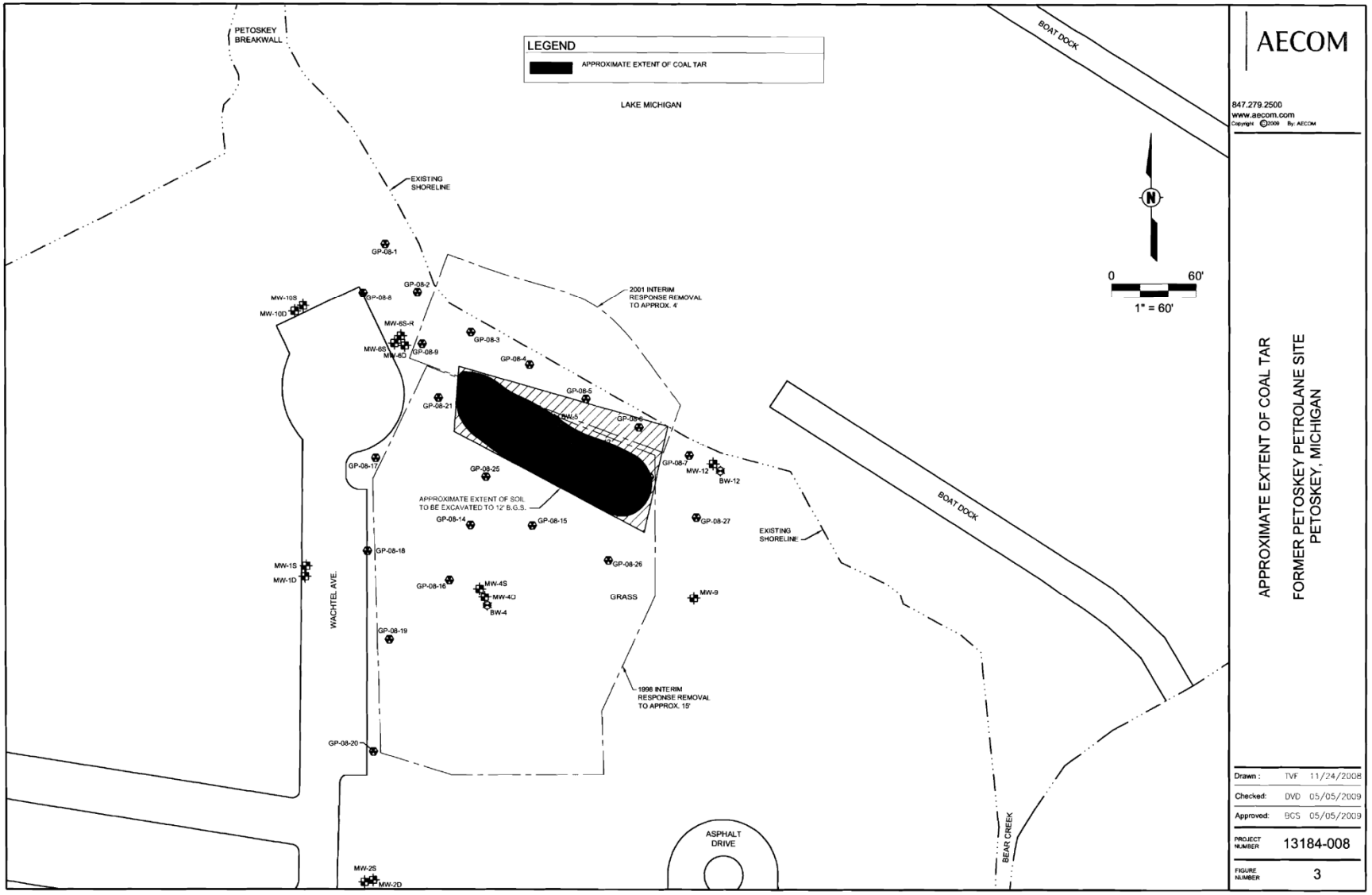
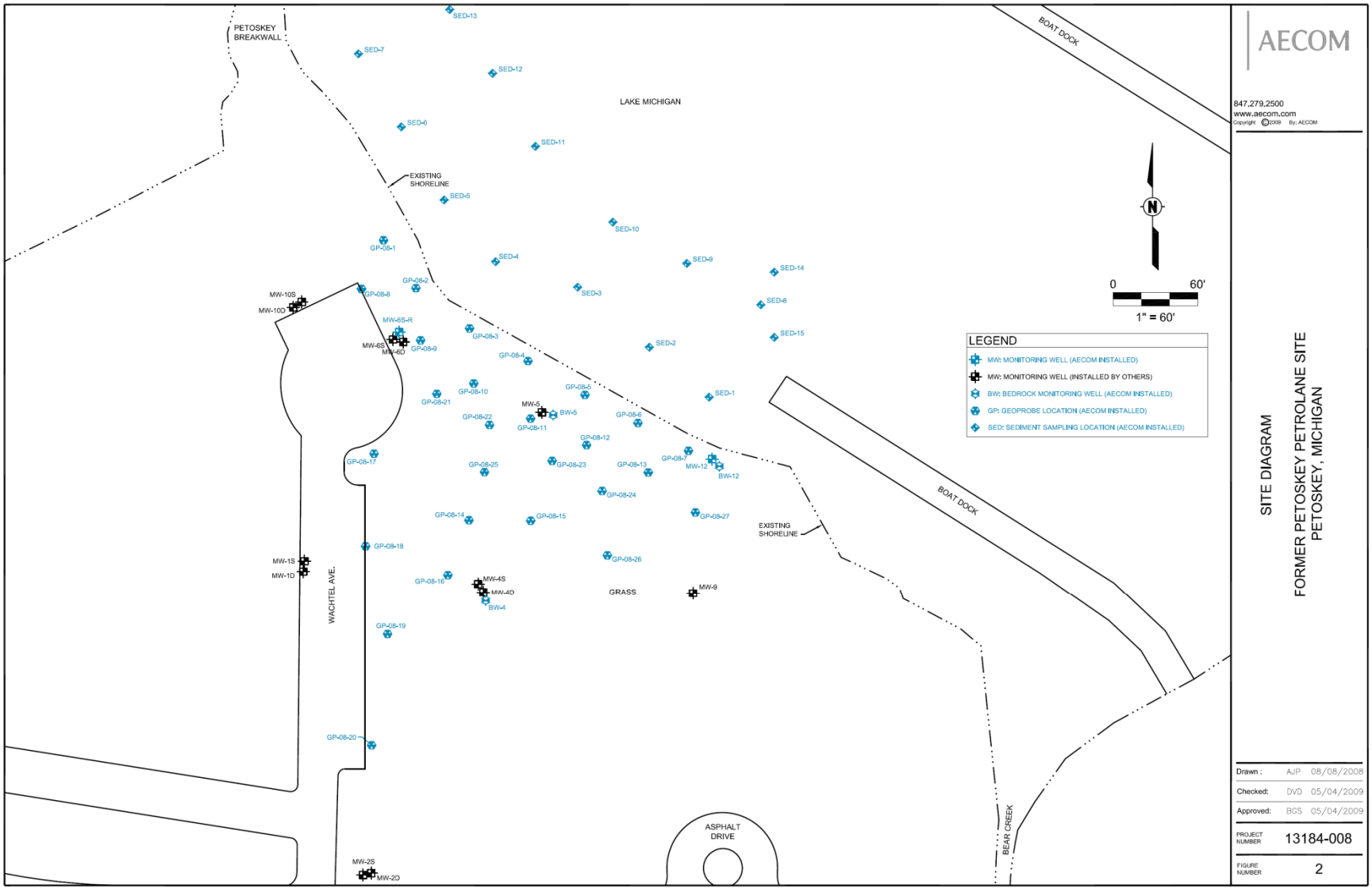


Figure 6. Sampling locations for the 2008 Remedial Investigation at the Former Petoskey Petrolane site (Emmet County, Michigan).



address children or fishermen standing in the sediments (Appendix A). Only benzo(a)pyrene exceeded its adjusted DCC of 3,400 micrograms per kilogram (µg/kg). Table 1 shows the concentrations of chemicals detected in the sediment and comparison to the generic and adjusted DCC. Chemicals without adjusted criteria are discussed in the next section of this document.

The GSI criterion for mercury in groundwater is 0.0013 micrograms per liter (µg/L). This is to prevent the bioaccumulation of harmful amounts of methylmercury in fish tissue eaten by wildlife or humans (MDEQ 2009). MDEQ guidance identifies the use of U.S. Environmental Protection Agency (EPA) Method 1631 to obtain a low enough detection limit for this criterion (MDEQ 2004b, c). The RI report indicated that a method with a higher detection limit (0.2 µg/L) was used and that all samples fell below this limit (i.e., mercury was not detected). The method used (EPA Method 7470/245.1) does not provide an adequate comparison of the samples to the GSI criterion. MDCH requested that the groundwater be analyzed using EPA Method 1631 and the mercury concentration compared to the GSI criterion of 0.0013 µg/L. MDEQ conducted this sampling on August 18, 2009. The results are discussed in the next section.

The GCC is applicable only to groundwater. People playing or wading in the water at the former Petoskey Petrolane site would be exposed to surface water. The MDEQ does not generate criteria that address dermal contact with surface water. However, inputs used to derive the GCC can be altered to obtain an informal screening level to address exposure to surface water (State of Michigan 2002a, b). MDCH derived screening levels to address children playing and fishermen wading in the water (Appendix B), but there are no surface water data available. Although MDCH does not find it necessary to sample surface or pore water at the site, concerned community members may request it of their local health officials. In that case, the adjusted screening levels can be used for comparison. MDCH does not find it necessary to sample the water, based on the following:

- Those VOC groundwater samples at the Petrolane site that exceed their adjusted screening levels addressing surface water contact are within an order of magnitude (a factor of 10) of their respective screening levels. Any groundwater venting to the surface water would be diluted with water already in Little Traverse Bay and Lake Michigan and entering from Bear River.
- As discussed in Appendix B, adjustment of the GCC for certain PAHs is not applicable, depending on the chemical's molecular weight and octanol-water coefficient (MDEQ 2006a). Research suggests that PAHs tend to stay adsorbed to soils and do not readily enter the water column or penetrate beyond the outermost layer of skin (ATSDR 1999).
- The highest concentration of each metal in the groundwater samples does not exceed its respective generic GCC or adjusted screening level, suggesting that concentrations venting to surface water would not exceed the screening levels either.

*Low-Level Analysis for Mercury in Groundwater*

Per a request from MDCH, MDEQ conducted sampling and analysis of groundwater from the GSI monitoring wells at the Petoskey Petrolane site on August 18, 2009, using low-level mercury sampling specifications (MDEQ 2004c). Field staff sampled from nine wells. Five samples had detections of mercury, four of which exceeded the GSI criterion of 0.0013 µg/L (range = 0.0012-0.060 µg/L).

Table 1. Chemicals detected in sediment at the Former Petoskey Petrolane site (Emmet County, Michigan) and comparison to generic and adjusted Direct Contact Criteria.

| Chemical | No. detections / No. samples | Maximum concentration | Generic DCC | No. samples exceeding Generic DCC | Adjusted DCC | | | | No. samples exceeding Adjusted DCC |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | fisher-c | fisher-nc | child-c | child-nc | |
| *VOCs (ug/kg)* | | | | | | | | | |
| Ethylbenzene | 1 / 37 | 4.80E+02 | 1.40E+05 | 0 | | 3.4E+07 | | 1.6E+06 | 0 |
| Isopropyl benzene | 1 / 37 | 1.70E+02 | 3.90E+05 | 0 | | 3.8E+07 | | 1.9E+06 | 0 |
| p-Isopropyl toluene[A] | 1 / 37 | 8.00E+01 | NA | 0 | | | | | 0 |
| Toluene | 2 / 37 | 1.70E+02 | 2.50E+05 | 0 | | 7.7E+07 | | 3.7E+06 | 0 |
| 1,2,3-Trimethylbenzene[A] | 1 / 37 | 2.80E+02 | NA | 0 | | | | | 0 |
| 1,2,4-Trimethylbenzene | 1 / 37 | 8.30E+02 | 1.10E+05 | 0 | | 4.9E+07 | | 2.4E+06 | 0 |
| 1,3,5-Trimethylbenzene | 1 / 37 | 1.70E+02 | 9.40E+04 | 0 | | 4.9E+07 | | 2.4E+06 | 0 |
| Xylenes | 1 / 37 | 3.20E+02 | 2.5E+0.5 | 0 | | 6.3E+08 | | 3.0E+07 | 0 |
| *PNAs (PAHs) (ug/kg)* | | | | | | | | | |
| 2-Methylnaphthalene | 3 / 37 | 4.60E+03 | 8.10E+06 | 0 | | 1.3E+07 | | 6.1E+05 | 0 |
| Acenaphthene | 14 / 37 | 8.40E+03 | 4.10E+07 | 0 | | 6.3E+07 | | 3.0E+06 | 0 |
| Anthracene | 24 / 37 | 6.50E+03 | 2.30E+08 | 0 | | 3.5E+08 | | 1.7E+07 | 0 |
| Benzo(a)anthracene | 34 / 37 | 7.00E+03 | 2.00E+04 | 0 | 6.4E+04 | | 3.4E+04 | | 0 |
| **Benzo(a)pyrene** | 26 / 37 | 6.40E+03 | 2.00E+03 | **1** | 6.4E+03 | | 3.4E+03 | | **1** |
| Benzo(b)fluoranthene | 32 / 37 | 8.10E+03 | 2.00E+04 | 0 | 6.4E+04 | | 3.4E+04 | | 0 |
| Benzo(g,h,i)perylene | 15 / 37 | 1.90E+03 | 2.50E+06 | 0 | | 2.6E+06 | | 9.4E+04 | 0 |
| Benzo(k)fluoranthene | 19 / 37 | 2.80E+03 | 2.00E+05 | 0 | 6.4E+05 | | 3.4E+05 | | 0 |
| Chrysene | 34 / 37 | 6.20E+03 | 2.00E+06 | 0 | 6.4E+06 | | 3.4E+06 | | 0 |
| Dibenzo(a,h)anthracene | 1 / 37 | 2.30E+02 | 2.00E+03 | 0 | 6.4E+03 | | 3.4E+03 | | 0 |
| Fluoranthene | 37 / 37 | 1.30E+04 | 4.60E+07 | 0 | | 5.4E+07 | | 2.1E+06 | 0 |
| Fluorene | 16 / 37 | 5.10E+03 | 2.70E+07 | 0 | | 4.2E+07 | | 2.0E+06 | 0 |
| Indeno(1,2,3-cd)pyrene | 16 / 37 | 1.90E+03 | 2.00E+04 | 0 | 6.4E+04 | | 3.4E+04 | | 0 |
| Naphthalene | 9 / 37 | 8.60E+03 | 1.60E+07 | 0 | | 2.5E+07 | | 1.2E+06 | 0 |
| Phenanthrene | 36 / 37 | 1.90E+04 | 1.60E+06 | 0 | | 2.5E+06 | | 1.2E+05 | 0 |
| Pyrene | 37 / 37 | 1.70E+04 | 2.90E+07 | 0 | | 3.4E+07 | | 1.3E+06 | 0 |

Table 1 (cont'd). Chemicals detected in sediment at the Former Petoskey Petrolane site (Emmet County, Michigan) and comparison to generic and adjusted Direct Contact Criteria.

| Chemical | No. detections / No. samples | Maximum concentration | Generic DCC | No. samples exceeding Generic DCC | Adjusted DCC | | | | No. samples exceeding Adjusted DCC |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | fisher-c | fisher-nc | child-c | child-nc | |
| *Metals (mg/kg)* | | | | | | | | | |
| Arsenic | 14 / 37 | 2.9 | 7.6 | 0 | 42 | 242 | 39 | 15 | 0 |
| Barium | 37 / 37 | 28 | 37,000 | 0 | | 87,657 | | 10,614 | 0 |
| Cadmium | 5 / 37 | 0.49 | 550 | 0 | | 1,525 | | 698 | 0 |
| Chromium | 32 / 37 | 12 | 790,000 | 0 | | 6,011 | | 728 | 0 |
| Copper | 33 / 37 | 15 | 20,000 | 0 | | 47,585 | | 5,762 | 0 |
| Lead[A] | 37 / 37 | 48 | 400 | 0 | | | | | 0 |
| Selenium | 9 / 37 | 0.78 | 2,600 | 0 | | 6,261 | | 758 | 0 |
| Silver | 3 / 37 | 0.43 | 2,500 | 0 | | 5,886 | | 713 | 0 |
| Zinc | 37 / 37 | 57 | 170,000 | 0 | | 413,240 | | 50,036 | 0 |
| *Others (mg/kg)* | | | | | | | | | |
| Ammonia[A] | 37 / 37 | 84 | NA | 0 | | | | | 0 |
| Total Cyanide[B] | 15 / 37 | 0.37 | 12 | 0 | | 4,219 | | 3,140 | 0 |

Acronyms and Abbreviations

| | | | |
|---|---|---|---|
| ug | microgram | NA | not available |
| c | for carcinogen | nc | for non-carcinogen |
| DCC | Direct Contact Criteria | PNAs | polynuclear aromatic compounds |
| kg | kilogram | PAHs | polycyclic aromatic hydrocarbons |
| mg | milligram | VOC | volatile organic compound |

Note:

A. See "Chemicals Without Adjusted Screening Levels" section for discussion.

B. Although "Available Cyanide" was also reported, there is no DCC for it. If results for Total Cyanide are acceptable, then Available Cyanide results are also acceptable (L. Dykema, MDCH, personal communication, 2009).

Historical sampling for background mercury concentrations in groundwater in the Petoskey area suggests that naturally-occurring mercury in the groundwater exists but below the GSI criterion (M. Kendzierski, MDEQ-RRD, personal communication, 2009). Thus, the detections seen at the Petrolane site are probably due to human activity. The wells with exceedances (MW-6S-R, -6D, -2S, and -10S) are adjacent to Wachtel Avenue and outside of the areas previously excavated (Figure 5). It is possible that contamination from the Petrolane site is the cause of the exceedances. Alternatively, the contamination could be coming from the Petoskey Manufacturing Company Superfund site, which is across Wachtel Avenue from the Petrolane site, south of Water Street. The main chemicals of concern at the Petoskey Manufacturing site were VOCs, but mercury was also present (EPA 2005a).

Further discussion of the mercury in the groundwater is in the *Exposure Pathway Analysis* and *Toxicological Evaluation* sections of this document.

Chemicals Without Adjusted Screening Levels

*p-Isopropyl Toluene*

p-Isopropyl toluene, a VOC, is also known as p-cymene. It is a component of solvents used as thinners for lacquers and varnishes, is a chemical intermediate in the production of p-cresol and other organic compounds, and is used in the flavor and fragrance industry. High concentration of liquid p-isopropyl toluene might irritatethe skin or eyes on contact. Breathing vapors does not appear to affect the nose or throat (HSDB 2009).

The concentrations of other VOCs detected in the sediments at the Petoskey Petrolane site are two to three orders of magnitude (100 to 1,000 times) less than their respective generic DCC and four to five orders of magnitude (10,000 to 100,000 times) less than their respective adjusted screening levels. It can be reasonably assumed that a screening level for p-isopropyl toluene, if it could be determined, would not be exceeded.

*1,2,3-Trimethylbenzene*

1,2,3-Trimethylbenzene is used in the manufacture of other chemicals, dyes, and perfumes. High concentrations of the chemical can irritate the eyes, skin, and respiratory tract (HSDB 2009). Isomers (chemicals with the same chemical formulas but different structural formulas) include 1,2,4- and 1,3,5-trimethylbenzene. If the screening level for 1,2,4- or 1,3,5-trimethylbenzene were used as a surrogate screening level for the 1,2,3- isomer, the concentration for 1,2,3-trimethylbenzene would be within acceptable limits (see Table 1). Also, for the reasons stated for p-isopropyl toluene above, it is not expected that 1,2,3-trimethylbenzene would exceed its screening level, if one were established.

*Dibenzofuran*

Dibenzofuran, a PAH, is used in the manufacture of heat-transfer oils and some dyes. It is a component of coal tar and is often found at sites where coal tar, coal tar products, or creosote compounds have been used. Toxicity data for dibenzofuran are lacking (HSDB 2009). With its octanol-water coefficient of 4.2 and molecular weight of 168.2 (MDEQ 2005), it will likely act similarly to other PAHs and not readily penetrate the outermost layer of skin.

*Lead*

The DCC for lead is calculated differently than the criteria for other chemicals. MDEQ uses the Integrated Exposure Uptake Biokinetic (IEUBK) Model and considers exposure to multiple sources of lead (soil, water, food, lead-based paint, air). The model estimates the increase in blood lead level. Lead is a potent neurotoxin (ATSDR 2007).

All of the adjusted screening levels for metals were greater than their respective generic DCC. There were no exceedances of the generic DCC for lead. Therefore, it can reasonably be assumed that there would be no exceedances of a sediment screening level for lead at this site.

*Ammonia*

The MDEQ Part 201 criteria footnotes indicate that the total concentration of all potential sources of nitrate-nitrogen (that from ammonia, nitrates, and nitrites) should not exceed the nitrate drinking water criterion when the groundwater is used as a source of drinking water (MDEQ 2005a). The concern with nitrate-nitrogen in the environment is when it enters drinking water. Infants receiving this water may suffer from methemoglobinemia ("blue-baby" syndrome), where the oxygen-carrying capacity of the blood is compromised (EPA 2009a). The potential for exposure to ammonia, and other groundwater contaminants, through the drinking-water pathway is discussed in the *Exposure Pathways Analysis* section.

Exposure Pathways Analysis

To determine whether persons are, have been, or are likely to be exposed to contaminants, MDCH evaluates the environmental and human components that could lead to human exposure. An exposure pathway contains five elements:

- a source of contamination
- contaminant transport through an environmental medium
- a point of exposure
- a route of human exposure
- a receptor population

An exposure pathway is considered complete if there is evidence, or a high probability, that all five of these elements are, have been, or will be present at a site. 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 2 details the potential exposure pathways at this site.

Table 2. Exposure pathway analysis for the Former Petoskey Petrolane site (Emmet County, Michigan).

| Source | Environmental Medium | Chemicals of Interest | Exposure Point | Exposure Route | Exposed Population | Time Frame | Exposure Likelihood |
|---|---|---|---|---|---|---|---|
| Coal tar from the Former Petoskey Petrolane site | Soil | VOCs, PAHs, metals | Soil and sand | Dermal, ingestion, inhalation | Workers at the site | Past | Complete |
| | | | | | Users of the public park at the site | Present | Incomplete |
| | | | | | | Future | Incomplete |
| | Sediment | VOCs, PAHs, metals | Off-shore sediments | Dermal, ingestion, inhalation | People wading or swimming | Past | Unlikely |
| | | | | | | Present | Potential |
| | | | | | | Future | Potential |
| | Groundwater | VOCs, PAHs, metals | Surface water | Dermal, ingestion, inhalation | People wading or swimming | Past | Unlikely |
| | | | | | | Present | Potential |
| | | | | | | Future | Potential |
| Previous industrial activity in the area | Groundwater | VOCs, PAHs, metals | Drinking water | Dermal, ingestion, inhalation | Residents, workers | Past | Potential |
| | | | | | | Present | Incomplete |
| | | | | | | Future | Incomplete |
| | | Mercury | Fish | Ingestion | Consumers of fish from the area | Past | Potential |
| | | | | | | Present | Potential |
| | | | | | | Future | Potential |

*Past Exposures*

It is likely that workers at the manufactured gas plant were exposed to coal tar constituents in the soil. The area was occupied by several industries in the past, making it unlikely that the bay near the site was used previously for swimming or wading.

*Present Exposures*

Currently, people are not exposed to the contamination in the soil because it is at least two feet below the ground surface.

Contaminants in the sediment were found at several depths, including within the first foot, suggesting that people wading or swimming in the harbor near the site are being exposed. The location where the benzo(a)pyrene exceedance occurred is outside of the "shallow-water" area and more in the boat-traffic area. The water depth at this location at the time of sampling was four feet. Due to the danger of swimming near boat traffic and the water depth likely being too deep for wading by children ages six to 11, it is unlikely that children would be consistently exposed to contamination at this location.

Because of the lack of surface water data, it is unknown whether people are being exposed to contaminants in the surface water. However, it is possible that contaminants in the upper sediments are entering the water column or that affected groundwater is venting to the harbor.

The area of Petoskey near the Petrolane site is served by municipal water, which is required to meet public drinking water quality standards. The municipal wells are very deep (250 to 500 feet [City of Petoskey 2008]), several miles to the west, and likely not affected by the contamination at the site. There are no known private drinking water wells near the Petrolane site (S.

Kendzierski, HDNM, personal communication, 2009). Therefore, people are not likely to be exposed to groundwater contaminants at the Petrolane site via the drinking-water pathway.

Mercury exists at low levels in the groundwater at the Petrolane site and may be venting to surface waters, ultimately ending up in fish tissue. Fishermen use the outlet of Bear River for fishing, primarily for steelhead and salmon (S. Kendzierski, HDNM, personal communication, 2009). The 2009 Michigan Family Fish Consumption Guide indicates that, of the fish species sampled in northern Lake Michigan, only walleye have consumption-restriction recommendations based on mercury levels (MDCH 2009). It is not known whether people eating fish from the waters near the Petoskey Petrolane site are following those recommendations. Because there is potential for exposure to mercury via consumption of contaminated fish, further discussion is in the *Toxicological Evaluation* section.

*Future Exposures*

During early fall of 2009, MDEQ excavated 6,600 tons of contaminated soils from the site, removing the potential for exposure via the direct-contact pathway. MDCH concludes that it is not necessary to dredge contaminated sediments to protect public health. Exposure will likely still occur but not at harmful levels. It is possible that contaminants in the sediments will enter the water column or that affected groundwater will vent to the surface water but any exposure to that water should not cause harm.

Toxicological Evaluation

*Mercury*

Mercury is a naturally occurring metal. In its elemental form, it is used in thermometers, barometers, and some electrical equipment (cathode ray tubes, switches). Mercury compounds are emitted to the air from coal-fired electrical plants and some manufacturing plants. Mercury is a global pollutant. Methylmercury, an organic mercury compound, is formed by bacteria in soil or water where airborne mercury compounds have deposited. Methlymercury builds up in the aquatic food chain, with higher concentrations being found in predator fish (ATSDR 1999). Mercury cannot be removed from the edible portion of fish.

Exposure to high levels of mercury can permanently damage the brain, kidneys, and developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Methylmercury exposure can have adverse cardiovascular effects for adults, resulting in elevated blood pressure and incidence of heart attack (ATSDR 1999).

People who eat fish from Michigan waters, regardless of whether or not their catch comes from waters near the Petoskey Petrolane site, might be exposed to levels of mercury in the fish that, *in the long-term*, may cause negative health effects. (The groundwater mercury concentrations at the Petrolane site do not pose an immediate concern.) People should use the Michigan Family Fish Consumption Guide to determine which fish from a particular water body are more likely to contain mercury and how to decide whether to eat their catch.

Consideration of Exposure to Multiple Chemicals

The evaluation above considers exposure to *individual* chemicals, however exposure usually occurs to a *mixture* of chemicals. To evaluate whether exposure to several non-carcinogenic chemicals may result in harm, risk assessors calculate the hazard quotient (HQ) of each chemical, then sum the quotients to determine an overall hazard index (HI). To calculate the HQ of a chemical, one must divide the expected dose by the acceptable dose. A value less than 1 for the HQ suggests that harm would not be expected, if exposure was to that chemical alone. A value less than 1 for the HI suggests that the mixture of chemicals would not cause harm (ATSDR 2004).

This concept of dose additivity is normally applied to compounds that induce the same effect by the same mode or mechanism of action (ATSDR 2004). The critical toxic effects caused by exposure to chemicals like those found at the Petoskey Petrolane site include liver, kidney, lung, stomach and skin injury or cancer; central nervous system effects; and blood effects. To grossly evaluate exposure to chemicals in sediments at this site, MDCH calculated an HI for the non-carcinogens, *regardless of critical effect* (Appendix C). (This would result in an over-estimation of the total hazard expected.) The resulting values were 0.007 for adults and 0.004 for children, using the same exposure assumptions made when calculating site-specific screening levels. If the chemicals were grouped by toxic mechanism, the HI values would be even lower. Even though additional exposure would occur via occasional swallowing of and skin contact with the water, the incremental increase in HI would likely no more than double or triple the total value. This suggests that exposure to the non-carcinogenic chemicals at the Petrolane site, as a mixture, would not result in harm.

To evaluate whether exposure to several carcinogenic chemicals may result in an unacceptable cancer risk, one calculates each individual chemical's risk and sums the results. Cancer risk is calculated by multiplying the expected exposure averaged over a 70-year lifespan by the cancer slope factor (EPA 2005b). Historically, cancer risk was applied only to adults, however the U.S. EPA has developed guidelines to estimate lifetime cancer risk when children are exposed. Due to lifestage differences, EPA suggests applying an age-dependent adjustment factor (ADAF) to the cancer risk calculation when the carcinogen is considered to be mutagenic (damages the body's genetic material) (EPA 2005c).

Some of the carcinogens present at the Petoskey Petrolane site, namely benzo(a)pyrene and dibenz(a,h)anthracene, are considered to be mutagenic (EPA 1994a, 1994b). To grossly evaluate the cancer risk from exposure of children to the sediments at this site, MDCH applied the ADAF to *all* individual risk calculations for children (Appendix C). (This would result in an over-estimation of the total cancer risk expected. No adjustment factor was applied when calculating the cancer risk from exposure of adults.) The resulting total cancer risks were 2 in 10 million for adults and 3 in 10 million for children. The State of Michigan uses 1 in 100,000 as its acceptable cancer risk (State of Michigan 2002). Similar to the discussions for HIs above, even though additional exposure would occur via occasional swallowing of and skin contact with the water, the incremental increase in cancer risk would likely be insignificant. This suggests that exposure to the carcinogenic chemicals at the Petrolane site, as a mixture, would not result in an unacceptable cancer risk.

Children's Health Considerations

In general, children may be at greater risk than adults from exposure to hazardous substances at sites of environmental contamination. Children engage in activities such as playing outdoors and hand-to-mouth behaviors that could increase their intake of hazardous substances. They are shorter than most adults, and therefore breathe dust, soil, and vapors found closer to the ground. Their lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. The developing body systems of children can sustain permanent damage if toxic exposures are high enough during critical growth stages. Fetal development involves the formation of the body's organs. Injury during key periods of prenatal growth and development could lead to malformation of organs (teratogenesis), disruption of function, and premature death. Exposure of the mother could lead to exposure of the fetus, via the placenta, or affect the fetus because of injury or illness sustained by the mother (ATSDR 1998). The implication for environmental health is that children can experience substantially greater exposures to toxicants in soil, water, or air than adults can.

Some of the chemicals present at the Petoskey Petrolane site were carcinogenic, however no unacceptable cancer risk is expected if children are exposed. Exposure to the non-carcinogens is not expected to be sufficient to cause harm.

Additional Public Health Concerns at the Site

During a visit to the site on June 6, 2009, MDCH noticed a flock of geese occupying the beach area. (Figure 2 shows the geese swimming near the beach.) There were goose droppings on the grass and sand. The droppings can pose a public health threat either directly or by contamination of surface water with *E. coli* bacteria. This beach is not on the MDEQ Beach Monitoring System database. It is unknown if the geese regularly occupy this area or if they will move to another location once the public starts using the beach. If the geese leave and the droppings are cleaned up, there should not be a concern.

Additionally, due to the marina's proximity to the beach, there is potential for additional bacterial contamination by accidental or illegal discharge of sewage from the boats using the marina.

## Community Health Concerns

MDCH is unaware of any health concerns voiced by the community regarding the Petrolane site.

## Conclusions

MDCH has determined that contact with contaminated sediments when wading at the Petoskey Petrolane site is not expected to cause harm. There is only one chemical (benzo[a]pyrene) at one location that exceeds its adjusted screening level. The location is outside of the swimming area, in deeper water, where boat traffic occurs.

MDCH has determined that contact with surface or pore water when wading or swimming at the Petoskey Petrolane site is not expected to cause harm and that it is not necessary to sample the water.

MDCH cannot determine whether the mercury in the groundwater at the Petoskey Petrolane site is significantly contributing to methylmercury levels in fish. Little Traverse Bay is part of the much larger Lake Michigan, which has multiple potential sources of mercury to it. An estimate of the contribution made by the Petoskey Petrolane site would likely have a high degree of uncertainty.

MDCH cannot determine whether there is a bacterial threat to public health at this site. Beach monitoring for *E. coli* in the water is necessary to determine if harmful bacterial levels exist.

**Recommendations**

1. Follow the advice in the Michigan Family Fish Consumption Guide.
2. Conduct beach monitoring sampling for *E. coli* to ensure that the beach is acceptable for recreational use.

**Public Health Action Plan**

1. MDCH will regularly update the Family Fish Consumption Guide based on fish contaminant data supplied by MDEQ. The guide is available to the public at www.michigan.gov/fishandgameadvisory
2. HDNM will add the beach to their beach-sampling program.

MDCH will remain available as needed for future consultation at this site.

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

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## Certification

This **Former Petoskey Petrolane** 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. Editorial review was completed by the cooperative agreement partner.

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

Team Leader, CAPEB, DHAC, ATSDR

Appendix A: Adjusting the Direct Contact Criteria to evaluate exposure to contaminated sediments at the former Petoskey Petrolane site

The MDEQ Part 201 program does not generate criteria for sediments or for recreational scenarios. However, exposure assumptions for the Direct Contact Criteria (DCC), which represent soil concentrations protective against adverse health effects due to long-term ingestion of and dermal contact with contaminated soil, may be modified to obtain an informal screening value for occasional contact with sediments (State of Michigan 2002a, b). For this exercise, MDCH evaluated two possible scenarios: an adult wading offshore while fishing and a child, from age 6 to 11, swimming and playing in the water.

The algorithm used to derive the Residential/Commercial I DCC for a carcinogen is (MDEQ 2005b):

$$DCC_{carcinogen} = \frac{TR \times AT_c \times CF}{SF \times [(EF_i \times IF \times AE_i) + (EF_d \times DF \times AE_d)]}$$

The algorithm used to derive the Residential/Commercial I DCC for a noncarcinogen is (MDEQ 2005b):

$$DCC_{noncarcinogen} = \frac{THQ \times RfD \times AT_{nc} \times CF \times RSC}{(EF_i \times IF \times AE_i) + (EF_d \times DF \times AE_d)}$$

Inputs Specific To Carcinogen Equation:

**TR** is the target risk level, or the acceptable number of cancer cases above the background rate. This is typically set between 1 in 10,000 (1E-4) and 1 in 1,000,000 (1E-6) people. The State of Michigan has set the acceptable risk level as 1 additional cancer in 100,000 people (**1E-5**) (State of Michigan 2002c). The TR is unitless.

**$AT_c$** is the averaging time, in days, for carcinogens. In risk assessment, it is generally accepted that any exposure to a carcinogen increases one's risk of developing cancer during a lifetime (although not all exposures will result in cancer developing). The default lifetime span is 70 years which, multiplied by 365 days per year, is **25,550 days** (MDEQ 2005b).

**SF** is the cancer slope factor of a chemical, which is an estimate of the increased cancer risk from a lifetime exposure to a chemical (EPA 2009b). It is a probability estimate that is used only for comparative purposes and not a predictive tool. **Table A-1** shows the slope factors for each chemical evaluated here.

Inputs Specific To Noncarcinogen Equation:

**THQ** is the target hazard quotient for noncarcinogens and is unitless. The hazard quotient is the expected dose divided by the acceptable, or reference, dose. A THQ of **1**, used here, ensures that the dose to which a person may be exposed at this site does not exceed the reference value.

**RfD** is the Reference Dose, an estimated concentration of a chemical that a person can be exposed to orally daily over a period of time without experiencing negative health effects. Although uncertainty exists in deriving the estimate, the agency deriving the value (usually EPA)

strives to protect the most sensitive population (EPA 2009b). **Table A-1** shows the RfD for each chemical evaluated here.

**$AT_{nc}$** is the averaging time, in days, for noncarcinogens. For risk assessment of noncarcinogens, the risk of experiencing harm from an exposure increases with the exposure frequency and duration. For the adult scenario in this exercise, it is assumed that the fisherman wades at this location 120 days per year for 30 years (total of **3,600 days for fisherman**). (It is likely that people would not fish that frequently at one location, but this assumption will be protective of less avid fishermen.) For the child scenario, it is assumed that the child swims and wades at this location 48 days per year for 5 years (total of **240 days for child**). (This exposure assumption is based on data presented in the U.S. EPA Child-Specific Exposure Factors Handbook. Table 16-20 of the Handbook shows the number of times per month a respondent swam in a freshwater swimming pool. About half of the respondents age 6 to 11 swam five times per month whereas about 75% of the respondents swam 12 times per month [EPA 2008]. A swimming pool may be more attractive than a public beach for swimming. Selecting a higher value allows for protection of children frequently wading at the beach.)

**RSC** is the relative source contribution. There may be other exposures elsewhere that the receptor population may face beside the exposure at this site. For this exercise, it is assumed that all exposure to these chemicals occurs at the Petoskey Petrolane site. Therefore the RSC is **1 (100 percent)**.

Inputs Common To Both Equations:

**CF** is a conversion factor to convert from kilograms (kg) to micrograms (µg), which is a factor of 1,000,000,000 (**1E+9 µg/kg**).

**$EF_i$** and **$EF_d$** are the ingestion and dermal exposure frequencies, respectively. It is assumed in this exercise that adult exposure to the sediments occurs during the summer (90 days) and during warmer weather in the spring and fall (30 days) for a total of **120 days per year**. As discussed earlier, it is assumed that child exposure to the sediments occurs 48 days per year. It is possible that most fishermen and children would not be exposed that frequently, however this assumption should be protective of those who regularly use this beach. The generic DCC assumes that ingestion exposure occurs more frequently because the soil is tracked into the home and becomes available as dust (MDEQ 2005b). For this exercise, it is assumed that the sediments are washed off in the water before tracking occurs.

**IF** is the age-adjusted soil ingestion factor. The IF considers ingestion rate (IR), exposure duration (ED), and body weight (BW). (People usually do not eat soil intentionally but may consume small amounts of soil remaining on their skin when putting food or other items in their mouths.) The generic DCC assumes that a child through the age of six years eats 200 milligrams (mg) of soil per day, and that an adult eats 100 mg of soil per day for 24 years, for a total exposure duration of 30 years (MDEQ 2005b). In this exercise, the receptors are considered separately. For the fisherman, it is assumed that this person will eat 100 mg soil (sediment) per day for 30 years (EPA 1997). The average BW of an adult male, 18-74 years old, is 78.1 kg (EPA 1997). The equation for IF is (IRxED)/BW (MDEQ 2005b). Thus, **IF for the fisherman scenario is 38.4 mg-year/kg-day**. For the child, it is assumed that this person will eat 50 mg soil

(sediment) per day for the five-year span between ages six and 11. (The Child-Specific Exposure Factors Handbook recommends an ingestion rate of 100 mg per day when considering both soil and dust. Because it is assumed that the sediment is not tracked home and does not become household dust, the soil-only ingestion rate is 50 mg per day [EPA 2008].) The average BW of a child in this age range is 29.0 kg (EPA 2008). Thus, **IF for the child scenario is 8.6 mg-year/kg-day**.

**$AE_i$** and **$AE_d$** are the ingestion and dermal absorption efficiencies (science-based estimates of what percentage of a chemical is absorbed through the gastrointestinal tract or skin, respectively) and are chemical-specific. **Table A-1** shows the $AE_i$ and $AE_d$ for each chemical evaluated here.

**DF** is the age-adjusted soil dermal factor. It considers exposed skin surface area (SA) in square centimeters ($cm^2$), a soil adherence factor (AF) in milligrams per square centimeter ($mg/cm^2$), number of events per day (EV), exposure duration (ED), and body weight (BW). The generic DCC sums the respective subfactors for a child and adult (MDEQ 2005b). In this exercise, the receptors are considered separately. For the fisherman, it is assumed that the feet (1,310 $cm^2$) and the lower legs (2,560 $cm^2$), for a total of 3,870 $cm^2$ (EPA 1997), are exposed to the sediments twice per day for 30 years. The individual AFs for feet and lower legs in an adult, based on a study of reed gatherers, are 0.63 and 0.16 $mg/cm^2$, respectively. The weighted AF for the adult in this scenario is 0.32 $mg/cm^2$. (This is calculated by multiplying the SA and AF for each body part, summing the products, then dividing by the sum of the AFs.) As indicated earlier, the average BW of an adult male, 18-74 years old, is 78.1 kg. The equation for DF is (SAxEVxAFxED)/BW (MDEQ 2005b). Thus, **DF for the fisherman scenario is 475.7 mg-year/kg-day**. For the child, it is assumed that the feet (780 $cm^2$) and hands (540 $cm^2$) are exposed to the sediments, for a total of 1,320 $cm^2$ (EPA 2008), once per day for 5 years. The AF values for this scenario, 21 $mg/cm^2$ for feet and 0.49 $mg/cm^2$ for hands, were obtained from a study of children playing in tidal flats (EPA 2008, Shoaf et al 2005). The weighted AF for the child is 12.6 $mg/cm^2$. This value assumes a substantial amount of sediment remains adhered to the skin, even though the majority, if not all, of the sediment would be washed off. As indicated earlier, the average BW of a child, age 6-11, is 29.0 kg. Thus, **DF for the child scenario is 2867.6 mg-year/kg-day**.

The adjusted DCC equations, without chemical-specific inputs, are:

$$FishermanDCC_{carcinogen} = \frac{1E-5 \times 25{,}550 \times 1E+9}{SF \times [(120 \times 38.4 \times AE_i) + (120 \times 475.7 \times AE_d)]}$$

$$FishermanDCC_{noncarcinogen} = \frac{1 \times RfD \times 3{,}600 \times 1E+9 \times 1}{(120 \times 38.4 \times AE_i) + (120 \times 475.7 \times AE_d)}$$

$$ChildDCC_{carcinogen} = \frac{1E-5 \times 25{,}550 \times 1E+9}{SF \times [(48 \times 8.6 \times AE_i) + (48 \times 2867.6 \times AE_d)}$$

$$ChildDCC_{noncarcinogen} = \frac{1 \times RfD \times 600 \times 1E + 9 \times 1}{(48 \times 8.6 \times AE_i) + (48 \times 2867.6 \times AE_d)}$$

The chemical-specific inputs and the resulting adjusted DCC values are listed in Table A-1. (Note that MDEQ would not likely use the term "Adjusted DCC" but, instead, "site-specific sediment screening level." For purposes of this document, MDCH chose to use "Adjusted DCC" as the screening-level term.)

Table A-1. Chemical-specific parameters and sediment screening levels for the Petoskey Petrolane site (Emmet County, Michigan).

| Chemical | SF | RfD | AEi | AEd | Adjusted DCC | | | |
|---|---|---|---|---|---|---|---|---|
| *VOCs (ug/kg)* | | | | | fisher-c | fisher-nc | child-c | child-nc |
| Ethylbenzene | | 9.7E-02 | 1 | 0.1 | | 3.4E+07 | | 1.6E+06 |
| Isopropyl benzene | | 1.1E-01 | 1 | 0.1 | | 3.8E+07 | | 1.9E+06 |
| p-Isopropyl toluene[A] | | | | | | | | |
| Toluene | | 2.2E-01 | 1 | 0.1 | | 7.7E+07 | | 3.7E+06 |
| 1,2,3-Trimethylbenzene[A] | | | | | | | | |
| 1,2,4-Trimethylbenzene | | 1.4E-01 | 1 | 0.1 | | 4.9E+07 | | 2.4E+06 |
| 1,3,5-Trimethylbenzene | | 1.4E-01 | 1 | 0.1 | | 4.9E+07 | | 2.4E+06 |
| Xylenes | | 1.8E+00 | 1 | 0.1 | | 6.3E+08 | | 3.0E+07 |
| *PNAs (PAHs) (ug/kg)* | | | | | | | | |
| 2-Methylnaphthalene | | 3.6E-02 | 1 | 0.1 | | 1.3E+07 | | 6.1E+05 |
| Acenaphthene | | 1.8E-01 | 1 | 0.1 | | 6.3E+07 | | 3.0E+06 |
| Anthracene | | 1.0E+00 | 1 | 0.1 | | 3.5E+08 | | 1.7E+07 |
| Benzo(a)anthracene | 0.41 | | 0.5 | 0.13 | 6.4E+04 | | 3.4E+04 | |
| Benzo(a)pyrene | 4.1 | | 0.5 | 0.13 | 6.4E+03 | | 3.4E+03 | |
| Benzo(b)fluoranthene | 0.41 | | 0.5 | 0.13 | 6.4E+04 | | 3.4E+04 | |
| Benzo(g,h,i)perylene | | 7.1E-03 | 0.5 | 0.13 | | 2.6E+06 | | 9.4E+04 |
| Benzo(k)fluoranthene | 0.041 | | 0.5 | 0.13 | 6.4E+05 | | 3.4E+05 | |
| Chrysene | 0.0041 | | 0.5 | 0.13 | 6.4E+06 | | 3.4E+06 | |
| Dibenzo(a,h)anthracene | 4.1 | | 0.5 | 0.13 | 6.4E+03 | | 3.4E+03 | |
| Fluoranthene | | 1.2E-01 | 0.5 | 0.1 | | 5.4E+07 | | 2.1E+06 |
| Fluorene | | 1.2E-01 | 1 | 0.1 | | 4.2E+07 | | 2.0E+06 |
| Indeno(1,2,3-cd)pyrene | 0.41 | | 0.5 | 0.13 | 6.4E+04 | | 3.4E+04 | |
| Naphthalene | | 7.1E-02 | 1 | 0.1 | | 2.5E+07 | | 1.2E+06 |
| Phenanthrene | | 7.1E-03 | 1 | 0.1 | | 2.5E+06 | | 1.2E+05 |
| Pyrene | | 7.5E-02 | 0.5 | 0.1 | | 3.4E+07 | | 1.3E+06 |
| *Metals (mg/kg)* | | | | | | | | |
| Arsenic | 1.5 | 2.7E-04 | 0.5 | 0.03 | 4.2E+01 | 2.4E+02 | 3.9E+01 | 1.5E+01 |
| Barium | | 7.0E-02 | 0.5 | 0.01 | | 8.8E+04 | | 1.1E+04 |
| Cadmium | | 1.0E-03 | 0.5 | 0.001 | | 1.5E+03 | | 7.0E+02 |
| Chromium | | 4.8E-03 | 0.5 | 0.01 | | 6.0E+03 | | 7.3E+02 |
| Copper | | 3.8E-02 | 0.5 | 0.01 | | 4.8E+04 | | 5.8E+03 |
| Lead[A] | | | | | | | | |
| Selenium | | 5.0E-03 | 0.5 | 0.01 | | 6.3E+03 | | 7.6E+02 |
| Silver | | 4.7E-03 | 0.5 | 0.01 | | 5.9E+03 | | 7.1E+02 |
| Zinc | | 3.3E-01 | 0.5 | 0.01 | | 4.1E+05 | | 5.0E+04 |
| *Others (mg/kg)* | | | | | | | | |
| Ammonia[A] | | | 1 | 0.1 | | | | |
| Total Cyanide | | 5.4E-03 | 1 | 0 | | 4.2E+03 | | 3.1E+03 |

References: MDEQ 2005a, b

Acronyms and Abbreviations

| | | | |
|---|---|---|---|
| AEd | dermal absorption efficiency | PAH | polycyclic aromatic hydrocarbon |
| AEi | ingestion absorption efficiency | PNA | polynuclear aromatic compound |
| c | for carcinogen | RfD | Reference Dose |
| DCC | Direct Contact Criteria | SF | cancer slope factor |
| kg | kilogram | ug | microgram |
| mg | milligram | VOC | volatile organic compound |
| nc | for non-carcinogen | | |

Note: A. See "Chemicals Without Adjusted Screening Levels" section for discussion.

Appendix B: Adjusting the Groundwater Contact Criteria to evaluate exposure to surface water at the former Petoskey Petrolane site

The MDEQ Part 201 program does not generate criteria for contact with surface water. However, inputs to the Groundwater Contact Criteria (GCC), which represent groundwater concentrations protective against adverse health effects due to dermal (skin) exposure such as could occur in subsurface excavations, may be modified to obtain an informal screening value for occasional contact with surface water (State of Michigan 2002a, b). For this exercise, MDCH evaluated the same scenarios assumed in the exercise in Appendix A: an adult wading offshore while fishing and a child, from age 6 to 11, swimming and playing in the water. MDCH chose not to use MDEQ's "Rule 57" Water Quality Values (MDEQ 2004a, 2006b), which address, among other exposure scenarios, occasional swallowing of water from an area not used as a drinking-water source and ingestion of fish taken from the water body in question, because the larger concern here was that of dermal exposure, which is not addressed by Rule 57.

The algorithm used to derive the GCC for a carcinogen is (MDEQ 2006a):

$$GCC_{carcinogen} = \frac{BW \times AT_c \times TR \times CF_1}{SF \times SA \times SP \times EV \times EF \times ED \times CF_2}$$

The algorithm used to derive the GCC for a noncarcinogen is (MDEQ 2006a):

$$GCC_{noncarcinogen} = \frac{THQ \times RfD \times BW \times AT_{nc} \times CF_1}{SA \times SP \times EV \times EF \times ED \times CF_2}$$

Inputs Specific To Carcinogen Equation:

**TR** is the target risk level, or the acceptable number of cancer cases above the background rate. This is typically set between 1 in 10,000 (1E-4) and 1 in 1,000,000 (1E-6) people. The State of Michigan has set the acceptable risk level as 1 additional cancer in 100,000 people (**1E-5**) (State of Michigan 2002c). The TR is unitless.

**$AT_c$** is the averaging time, in days, for carcinogens. In risk assessment, it is generally accepted that any exposure to a carcinogen increases one's risk of developing cancer during a lifetime (although not all exposures will result in cancer developing). The default lifetime span is 70 years which, multiplied by 365 days per year, is **25,550 days** (MDEQ 2006a).

**SF** is the cancer slope factor of a chemical, which is an estimate of the increased cancer risk from a lifetime exposure to a chemical (EPA 2009b). It is a probability estimate that is used only for comparative purposes and not a predictive tool. **Table B-1** shows the slope factors for each chemical evaluated here.

Inputs Specific To Noncarcinogen Equation:

**THQ** is the target hazard quotient for noncarcinogens and is unitless. The hazard quotient is the expected dose divided by the acceptable, or reference, dose. A THQ of **1**, used here, ensures that the dose to which a person may be exposed at this site does not exceed the reference value.

**RfD** is the Reference Dose, an estimated concentration of a chemical that a person can be exposed to orally daily over a period of time without experiencing negative health effects. Although uncertainty exists in deriving the estimate, the agency deriving the value (usually EPA) strives to protect the most sensitive population (EPA 2009b). **Table B-1** shows the RfD for each chemical evaluated here.

**$AT_{nc}$** is the averaging time, in days, for noncarcinogens. For risk assessment of noncarcinogens, the risk of experiencing harm from an exposure increases with the exposure frequency and duration. For the adult scenario in this exercise, it is assumed that the fisherman wades at this location 120 days per year for 30 years (total of **3,600 days for fisherman**). (It is likely that people would not fish that frequently at one location, but this assumption will be protective of less avid fishermen.) For the child scenario, it is assumed that the child swims and wades at this location 48 days per year for 5 years (total of **240 days for child**). (This exposure assumption is based on data presented in the U.S. EPA Child-Specific Exposure Factors Handbook. Table 16-20 of the Handbook shows the number of times per month a respondent swam in a freshwater swimming pool. About half of the respondents age 6 to 11 swam five times per month whereas about 75% of the respondents swam 12 times per month [EPA 2008]. A swimming pool may be more attractive than a public beach for swimming. Selecting a higher value allows for protection of children frequently swimming at the beach.)

Inputs Common To Both Equations:

**BW** is the body weight. **The average BW of an adult male, 18-74 years old, is 78.1 kilograms (kg)** (EPA 1997)**. The average BW of a child, age 6 to 11, is 29.0 kg** (EPA 2008)**.**

**$CF_1$** is a conversion factor to convert from milligrams (mg) to micrograms (µg), which is a factor of 1,000 (**1E+3 µg/mg**).

**SA** is the skin surface area. **For the fisherman, it is assumed that the lower extremities (the entire legs and the feet, 7,610 $cm^2$)** (EPA 1997) **are exposed to the surface water. For the child, it is assumed that the whole body is exposed (10,800 $cm^2$)** (EPA 2008)**.**

**SP** is the skin penetration, in cm, per event. This is a chemical-specific value and is a function of the chemical's permeability coefficient ($K_p$) and the exposure time (ET). **For inorganic chemicals, SP is 0.001 cm/hour** unless there is scientific evidence of another value (MDEQ 2006). **The SP for organic chemicals requires several calculations** (MDEQ 2006a):

1. First, the **Kp**, permeability coefficient, value must be determined, using the octanol-water coefficient ($K_{ow}$) and the molecular weight (MW) of the chemical. The equation used is

   $$\log K_p = -2.80 + (0.67 \times \log K_{ow}) - (0.0056 - MW)$$

   Research has shown that this equation would not apply to chemicals with a log Kow < -1 and MW < 60, those with a log Kow > 4 and MW ranging from 150 to 350, or those with MW > 600. (For the Petoskey Petrolane site, the detected compounds that fit these categories are anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, dibenzofuran, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, phenanthrene, and pyrene.) However, the equation has been used to

develop conservative Kp values to derive the generic GCC and will be used for this exercise. $K_p$ values are in cm/hour.

2. Next, the ratio of the Kp of the stratum corneum (the outermost layer of skin) to the Kp of the viable epidermis (the outer layer of skin, involving 4-5 layers including the stratum corneum), **B**, is calculated:

$$B = K_p \times \frac{\sqrt{MW}}{2.6}$$

3. Then $\mathbf{D_{sc}}$, the chemical-specific diffusivity across the stratum corneum, whose thickness is represented by $\mathbf{I_{sc}}$, is calculated, in $cm^2$/hour:

$$D_{sc} = [10\text{^}(-2.80 - 0.0056MW)] \times I_{sc}$$

4. Next, the lag time, **τ** (tau), is calculated, in hours:

$$\tau = \frac{(I_{sc})\text{^}2}{6 \times D_{sc}}$$

5. The last step before calculating SP is to determine **t***, the time to reach steady-state. If B, calculated earlier, ≤ 0.6, then t* = 2.4 X τ. If B > 0.6, then:

$$t^* = \left(b - \sqrt{b\text{^}2 - c\text{^}2}\right)\left(\frac{I_{sc}\text{^}2}{D_{sc}}\right)$$

where $b = \frac{2(1+B)\text{^}2}{\pi} - c$ and $c = \frac{1 + 3B + 3B\text{^}2}{3(1+B)}$

6. If ET ≤ t*, then $SP = 2 \times K_p \times \sqrt{\frac{6 \times \tau \times ET}{\pi}}$

If ET > t*, then $SP = Kp \times \left[\frac{ET}{1+B} + 2\tau\left(\frac{1 + 3B + 3B\text{^}2}{(1+B)\text{^}2}\right)\right]$

For the adult, **it is assumed that the fisherman will be exposed 2 hours per day.** (This is a default value [MDEQ 2006].) The EPA Child-Specific Exposure Factors Handbook, Table 16-13, reports that a child age 6 to 11 will spend an average of 178 minutes (about 3 hours) per day in a pool, river, or lake (EPA 2008). For this exercise, it is assumed the child will go in and out of the water twice per day. Therefore, the total time of 3 hours is divided by 2 to result in a **child ET of 1.5 hours per day.**

**Table B-1** shows the inputs and resultant SPs for the chemicals detected at the Petoskey Petrolane site.

**EV** is the event frequency. **For the adult, it was assumed that the fisherman would go into the water once per day. It was assumed that the child would go swimming twice per day.**

**EF** is the exposure frequency. As discussed earlier, **it is assumed that the adult spends 120 days/year at the site and that the child spends 48 days per year at the site**.

**ED** is the exposure duration. As discussed earlier, **it is assumed that the adult will be exposed to the site over a 30-year duration and the child for 5 years.**

**$CF_2$** is a conversion factor to convert from cubic centimeters ($cm^3$) to liters (L), which is a factor of 1/1,000 (**1E-3 L/$cm^3$**).

The adjusted GCC equations, without chemical-specific inputs, are:

$$FishermanGCC_{carcinogen} = \frac{78.1 \times 25{,}550 \times 1E-5 \times 1E+3}{SF \times 7{,}610 \times SP \times 1 \times 120 \times 30 \times 1E-3}$$

$$FishermanGCC_{noncarcinogen} = \frac{1 \times RfD \times 78.1 \times 3{,}600 \times 1E+3}{7{,}610 \times SP \times 1 \times 120 \times 30 \times 1E-3}$$

$$ChildGCC_{carcinogen} = \frac{29 \times 25{,}550 \times 1E-5 \times 1E+3}{SF \times 10{,}800 \times SP \times 2 \times 48 \times 5 \times 1E-3}$$

$$ChildGCC_{noncarcinogen} = \frac{1 \times RfD \times 29 \times 240 \times 1E+3}{10{,}800 \times SP \times 2 \times 48 \times 5 \times 1E-3}$$

**Table B-1** shows the chemical-specific inputs and the resulting adjusted GCC values. (Note that MDEQ would not likely use the term "Adjusted GCC" but, instead, "site-specific surface-water screening level." For purposes of this document, MDCH chose to use "Adjusted GCC" as the screening-level term.)

Table B-1. Chemical-specific parameters and surface water screening levels for Petoskey Petrolane site (Emmet County, Michigan). (Units are micrograms per liter [parts per billion.)

| Chemical | SF | RfD | log Kow | MW | Kp | B | Dsc | tau | b | c | t* | SP fisher | SP child | Adjusted GCC fisher-c | Adjusted GCC fisher-nc | Adjusted GCC child-c | Adjusted GCC child-nc | Generic GCC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *VOCs* | | | | | | | | | | | | | | | | | | |
| Benzene | 0.029 | | 2.13 | 78.11 | 0.02 | 0.05 | 5.79E-07 | 0.29 | 0.34 | 0.37 | 0.69 | 0.04 | 0.03 | 6.5E+02 | | 1.6E+03 | | 1.1E+04 |
| Ethylbenzene | | 0.097 | 3.14 | 106.2 | 0.05 | 0.20 | 4.03E-07 | 0.41 | 0.44 | 0.48 | 0.99 | 0.14 | 0.11 | | 7.3E+03 | | 1.1E+03 | 1.7E+05 |
| Isopropyl benzene | | 0.11 | 3.6 | 122.2 | 0.08 | 0.36 | 3.28E-07 | 0.51 | 0.57 | 0.61 | 1.22 | 0.24 | 0.21 | | 4.7E+03 | | 7.1E+02 | 5.6E+04 |
| p-Isopropyl toluene[A] | | | | | | | | | | | | | | | | | | |
| 2-Methylnaphthalene | | 0.036 | 3.9 | 142.2 | 0.10 | 0.48 | 2.53E-07 | 0.66 | 0.69 | 0.70 | 1.58 | 0.34 | 0.29 | | 1.1E+03 | | 1.7E+02 | 2.5E+04 |
| n-Propylbenzene | | 0.011 | 3.69 | 120.2 | 0.10 | 0.42 | 3.36E-07 | 0.50 | 0.63 | 0.66 | 1.19 | 0.28 | 0.24 | | 4.1E+02 | | 6.1E+01 | 1.5E+04 |
| Toluene | | 0.22 | 2.75 | 92.14 | 0.03 | 0.12 | 4.83E-07 | 0.35 | 0.38 | 0.42 | 0.83 | 0.09 | 0.07 | | 2.6E+04 | | 4.2E+03 | 5.3E+05 |
| 1,2,3-Trimethylbenzene[A] | | | | | | | | | | | | | | | | | | |
| 1,2,4-Trimethylbenzene | | 0.14 | 3.67 | 120.2 | 0.10 | 0.41 | 3.36E-07 | 0.50 | 0.62 | 0.64 | 1.19 | 0.27 | 0.23 | | 5.3E+03 | | 8.0E+02 | 5.6E+04 |
| 1,3,5-Trimethylbenzene | | 0.14 | 3.5 | 120.2 | 0.07 | 0.31 | 3.36E-07 | 0.50 | 0.53 | 0.57 | 1.19 | 0.21 | 0.18 | | 6.9E+03 | | 1.0E+03 | 6.1E+04 |
| Xylenes | | 1.8 | 3.11 | 106.2 | 0.05 | 0.19 | 4.03E-07 | 0.41 | 0.43 | 0.47 | 0.99 | 0.13 | 0.11 | | 1.4E+05 | | 2.2E+04 | 1.9E+05 |
| *PNAs (PAHs)* | | | | | | | | | | | | | | | | | | |
| Acenaphthene | | 0.18 | 3.92 | 154.2 | 0.09 | 0.44 | 2.17E-07 | 0.77 | 0.65 | 0.67 | 1.84 | 0.32 | 0.27 | | 5.7E+03 | | 8.9E+02 | 4.2E+03 |
| Acenaphthylene | | 0.0071 | 3.6 | 152.3 | 0.06 | 0.27 | 2.22E-07 | 0.75 | 0.50 | 0.53 | 1.80 | 0.20 | 0.17 | | 3.7E+02 | | 5.7E+01 | 3.9E+03 |
| Anthracene | | 1 | 4.55 | 178.2 | 0.18 | 0.91 | 1.59E-07 | 1.05 | 1.25 | 1.09 | 4.02 | 0.71 | 0.62 | | 1.4E+04 | | 2.2E+03 | 4.3E+01 |
| Benzo(a)anthracene | 0.41 | | 5.7 | 228.3 | 0.55 | 3.20 | 8.35E-08 | 2.00 | 7.95 | 3.28 | 8.47 | 3.04 | 2.63 | 5.8E-01 | | 1.3E+00 | | 9.4E+00 |
| Benzo(a)pyrene | 4.1 | | 6.11 | 252.3 | 0.76 | 4.64 | 6.12E-08 | 2.72 | 15.57 | 4.70 | 11.86 | 4.90 | 4.24 | 3.6E-02 | | 8.2E-02 | | 1.0E+00 |
| Benzo(b)fluoranthene | 0.41 | | 6.2 | 252.3 | 0.87 | 5.33 | 6.12E-08 | 2.72 | 20.16 | 5.39 | 11.96 | 5.63 | 4.88 | 3.2E-01 | | 7.1E-01 | | 1.5E+00 |
| Benzo(g,h,i)perylene | | 0.0071 | 6.7 | 276.3 | 1.39 | 8.86 | 4.49E-08 | 3.71 | 52.98 | 8.89 | 16.72 | 10.43 | 9.03 | | 7.0E+00 | | 1.1E+00 | 1.0E+00 |
| Benzo(k)fluoranthene | 0.041 | | 6.2 | 252.3 | 0.87 | 5.33 | 6.12E-08 | 2.72 | 20.16 | 5.39 | 11.96 | 5.63 | 4.88 | 3.2E+00 | | 7.1E+00 | | 1.0E+00 |
| Carbazole | 0.01 | | 3.59 | 167.2 | 0.05 | 0.23 | 1.83E-07 | 0.91 | 0.46 | 0.50 | 2.18 | 0.17 | 0.15 | 4.2E+02 | | 9.5E+02 | | 7.4E+03 |
| Chrysene | 0.0041 | | 5.7 | 228.3 | 0.55 | 3.20 | 8.35E-08 | 2.00 | 7.95 | 3.28 | 8.47 | 3.04 | 2.63 | 5.8E+01 | | 1.3E+02 | | 1.6E+00 |
| Dibenzo(a,h)anthracene | 4.1 | | 6.69 | 278.4 | 1.33 | 8.53 | 4.38E-08 | 3.81 | 49.25 | 8.56 | 17.13 | 10.14 | 8.78 | 1.8E-02 | | 4.0E-02 | | 2.0E+00 |
| Dibenzofuran[A] | | | 4.2 | 168.2 | 0.12 | 0.59 | 1.81E-07 | 0.92 | 0.81 | 0.80 | 2.21 | 0.44 | 0.38 | | | | | |
| Fluoranthene | | 0.12 | 5.12 | 202.2 | 0.31 | 1.72 | 1.17E-07 | 1.43 | 2.87 | 1.84 | 5.73 | 1.47 | 1.27 | | 8.4E+02 | | 1.3E+02 | 2.1E+02 |
| Fluorene | | 0.12 | 4.21 | 166.2 | 0.12 | 0.61 | 1.86E-07 | 0.90 | 0.83 | 0.82 | 3.59 | 0.46 | 0.39 | | 2.7E+03 | | 4.1E+02 | 2.0E+03 |
| Indeno(1,2,3-cd)pyrene | 0.41 | | 6.65 | 276.3 | 1.28 | 8.20 | 4.49E-08 | 3.71 | 45.66 | 8.23 | 16.67 | 9.66 | 8.36 | 1.8E-01 | | 4.2E-01 | | 2.0E+00 |
| Naphthalene | | 0.071 | 3.36 | 128.2 | 0.05 | 0.24 | 3.04E-07 | 0.55 | 0.47 | 0.51 | 1.32 | 0.16 | 0.14 | | 4.5E+03 | | 6.9E+02 | 3.1E+04 |
| Phenanthrene | | 0.0071 | 4.6 | 178.2 | 0.19 | 0.99 | 1.59E-07 | 1.05 | 1.36 | 1.15 | 4.03 | 0.77 | 0.67 | | 9.5E+01 | | 1.4E+01 | 1.0E+03 |
| Pyrene | | 0.075 | 5.11 | 202.3 | 0.31 | 1.69 | 1.17E-07 | 1.43 | 2.81 | 1.82 | 5.73 | 1.45 | 1.25 | | 5.3E+02 | | 8.0E+01 | 1.4E+02 |

Table B-1 (cont'd). Chemical-specific parameters and surface water screening levels for Petoskey Petrolane site (Emmet County, Michigan). (Units are micrograms per liter [parts per billion.)

| Chemical | SF | RfD | log Kow | MW | Kp | B | Dsc | tau | b | c | t* | SP fisher | SP child | Adjusted GCC fisher-c | Adjusted GCC fisher-nc | Adjusted GCC child-c | Adjusted GCC child-nc | Generic GCC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | | | | | | | | | | | | | | | | | | |
| Arsenic | 1.5 | 0.0003 | | | 0.001 | | | | | | | 0.001 | 0.0015 | 4.9E+02 | 2.8E+03 | 6.4E+02 | 2.4E+02 | 4.3E+03 |
| Barium | | 0.07 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 7.2E+05 | | 6.3E+04 | 1.4E+07 |
| Cadmium | | 0.001 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 1.0E+04 | | 9.0E+02 | 1.9E+05 |
| Chromium | | 0.0048 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 4.9E+04 | | 4.3E+03 | 4.6E+05 |
| Copper | | 0.038 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 3.9E+05 | | 3.4E+04 | 7.4E+06 |
| Lead[A] | | | | | 0.001 | | | | | | | 0.001 | 0.0015 | | | | | |
| Mercury | | 0.0003 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 3.1E+03 | | 2.7E+02 | 5.6E+01 |
| Selenium | | 0.005 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 5.1E+04 | | 4.5E+03 | 9.7E+05 |
| Silver | | 0.0047 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 4.8E+04 | | 4.2E+03 | 1.5E+06 |
| Zinc | | 0.33 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 3.4E+06 | | 3.0E+05 | 1.1E+08 |
| **Others** | | | | | | | | | | | | | | | | | | |
| Unionized ammonia | | NA | NA | | 0.001 | | | | | | | 0.001 | 0.0015 | | | | | |
| Cyanide | | 0.0054 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 5.5E+04 | | 4.8E+03 | 5.7E+04 |
| Nitrate/nitrite | | 0.1 | | | 0.001 | | | | | | | 0.001 | 0.0015 | | 1.0E+06 | | 9.0E+04 | 5.7E+04 |

References: MDEQ 2005a, 2006a

Acronyms and Abbreviations:

| | | | | | |
|---|---|---|---|---|---|
| B | Kp ratio (stratum corneum:viable epidermis) | MW | molecular weight | SF | cancer slope factor |
| c | for carcinogen | NA | not available | SP | skin penetration per event |
| Dsc | effective diffusivity across stratum corneum | nc | for non-carcinogen | t* | time to reach steady-state |
| GCC | Groundwater Contact Criteria | PAH | polycyclic aromatic hydrocarbon | tau | lag time |
| Kow | octanol-water coefficient | PNA | polynuclear aromatic compound | VOC | volatile organic compound |
| Kp | permeability coefficient | RfD | Reference Dose | | |

Note:

A. See "Chemicals Without Adjusted Screening Levels" section for discussion.

## Appendix C. Gross determination of the hazard index and cancer risk of exposure to contaminants in sediment at the Petoskey Petrolane site

To grossly evaluate exposure to the mixture of noncarcinogens in the sediment at the Petoskey Petrolane site, MDCH calculated each chemical's Hazard Quotient (HQ), then summed the quotients, regardless of critical toxicological effect to obtain a Hazard Index (HI). To calculate the HQ of a chemical, one must divide the expected dose by the acceptable dose (ATSDR 2004). The expected dose was obtained by multiplying the highest sediment concentration of the chemical by the ingestion rate, dividing it by the body weight, and adjusting the value for intermittent exposure (multiplying by days exposed divided by 365 days per year). For this scenario, a child age 6 to 12 years might eat 50 grams of soil (sediment) per day, 48 days out of the year. The body weight (BW) of a child in that age range is 29 kilograms (kg) (EPA 2008). An adult might eat 100 grams of soil (sediment) per day, 120 days out of the year. The average BW of an adult male, 18 to 74 years old, is 78.1 kg (EPA 1997).

To grossly evaluate exposure to the mixture of carcinogens in the sediment at the Petoskey Petrolane site, MDCH calculated each chemical's cancer risk, then summed the risks. Cancer risk is calculated by multiplying the expected exposure averaged over a 70-year lifespan by the cancer slope factor (EPA 2005b). An age-dependent adjustment factor (ADAF) is applied to the calculation to estimate lifetime cancer risk when children are exposed and the chemical is mutagenic (damages the body's genetic material) (EPA 2005c). Similar to the HQ/HI calculations above, MDCH considered exposure to the highest concentration, rather than average the concentrations, of a chemical.

Table C-1 shows the calculated values and resulting gross HIs and cancer risks for adults and children exposed to the sediments at the Petoskey Petrolane site.

Table C-1. Gross hazard indices and aggregate cancer risks of the chemicals in the sediment at the Petoskey Petrolane site.

| *VOCs* | [Sediment][A] | Child Sed dose[B] | Adult Sed dose[B] | RfD[B] | Child HQ | Adult HQ | Adult Lifetime Daily Dose | CSF | Cancer Risk (adult) | Child Daily Dose | Cancer Risk (child) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 0 | 0.00E+00 | 0.00E+00 | | | | 0 | 0.029 | 0.E+00 | 0 | 0 |
| Ethylbenzene | 0.48 | 1.09E-07 | 2.02E-07 | 0.097 | 1.12E-06 | 2.08E-06 | | | | | |
| Isopropyl benzene | 0.17 | 3.85E-08 | 7.16E-08 | 0.11 | 3.50E-07 | 6.51E-07 | | | | | |
| **p-Isopropyl toluene[C]** | 0.08 | 1.81E-08 | 3.37E-08 | | | | | | | | |
| 2-Methylnaphthalene | 4.6 | 1.04E-06 | 1.94E-06 | 0.036 | 2.90E-05 | 5.38E-05 | | | | | |
| Toluene | 0.17 | 3.85E-08 | 7.16E-08 | 0.22 | 1.75E-07 | 3.25E-07 | | | | | |
| **1,2,3-Trimethylbenzene[C]** | 0.28 | 6.35E-08 | 1.18E-07 | | | | | | | | |
| 1,2,4-Trimethylbenzene | 0.83 | 1.88E-07 | 3.49E-07 | 0.14 | 1.34E-06 | 2.50E-06 | | | | | |
| 1,3,5-Trimethylbenzene | 0.17 | 3.85E-08 | 7.16E-08 | 0.14 | 2.75E-07 | 5.11E-07 | | | | | |
| Xylenes | 0.32 | 7.26E-08 | 1.35E-07 | 1.8 | 4.03E-08 | 7.48E-08 | | | | | |
| *PNAs (PAHs)* | | | | | | | | | | | |
| Acenaphthene | 8.4 | 1.90E-06 | 3.54E-06 | 0.18 | 1.06E-05 | 1.96E-05 | | | | | |
| Anthracene | 6.5 | 1.47E-06 | 2.74E-06 | 1 | 1.47E-06 | 2.74E-06 | | | | | |
| Benzo(a)anthracene | 7 | 1.59E-06 | 2.95E-06 | | | | 3.84E-08 | 0.41 | 2.E-08 | 1.72E-08 | 2.1E-08 |
| Benzo(a)pyrene | 6.4 | 1.45E-06 | 2.69E-06 | | | | 3.51E-08 | 4.1 | 1.E-07 | 1.58E-08 | 1.9E-07 |
| Benzo(b)fluoranthene | 8.1 | 1.84E-06 | 3.41E-06 | | | | 4.44E-08 | 0.41 | 2.E-08 | 2.00E-08 | 2.5E-08 |
| Benzo(g,h,i)perylene | 1.9 | 4.31E-07 | 8.00E-07 | 0.0071 | 6.07E-05 | 1.13E-04 | | | | | |
| Benzo(k)fluoranthene | 2.8 | 6.35E-07 | 1.18E-06 | | | | 1.54E-08 | 0.041 | 6.E-10 | 6.90E-09 | 8.5E-10 |
| Chrysene | 6.2 | 1.41E-06 | 2.61E-06 | | | | 3.40E-08 | 0.0041 | 1.E-10 | 1.53E-08 | 1.9E-10 |
| Dibenzo(a,h)anthracene | 0.23 | 5.21E-08 | 9.68E-08 | | | | 1.26E-09 | 4.1 | 5.E-09 | 5.67E-10 | 7.0E-09 |
| Fluoranthene | 13 | 2.95E-06 | 5.47E-06 | 0.12 | 2.46E-05 | 4.56E-05 | | | | | |
| Fluorene | 5.1 | 1.16E-06 | 2.15E-06 | 0.12 | 9.64E-06 | 1.79E-05 | | | | | |
| Indeno(1,2,3-cd)pyrene | 1.9 | 4.31E-07 | 8.00E-07 | | | | 1.04E-08 | 0.41 | 4.E-09 | 4.68E-09 | 5.8E-09 |
| Naphthalene | 8.6 | 1.95E-06 | 3.62E-06 | 0.071 | 2.75E-05 | 5.10E-05 | | | | | |
| Phenanthrene | 19 | 4.31E-06 | 8.00E-06 | 0.0071 | 6.07E-04 | 1.13E-03 | | | | | |
| Pyrene | 17 | 3.85E-06 | 7.16E-06 | 0.075 | 5.14E-05 | 9.54E-05 | | | | | |

Table C-1 (cont'd). Gross hazard indices and aggregate cancer risks of the chemicals in the sediment at the Petoskey Petrolane site.

| | [Sediment][A] | Child Sed dose[B] | Adult Sed dose[B] | RfD[A] | Child HQ | Adult HQ | Adult Lifetime Daily Dose | CSF | Cancer Risk (adult) | Child Daily Dose | Cancer Risk (child) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Metals* | | | | | | | | | | | |
| Arsenic | 2.9 | 6.58E-07 | 1.22E-06 | 0.00027 | 2.44E-03 | 4.52E-03 | 1.59E-08 | 1.5 | 2.E-08 | 7.14E-09 | 3.2E-08 |
| Barium | 28 | 6.35E-06 | 1.18E-05 | 0.07 | 9.07E-05 | 1.68E-04 | | | | | |
| Cadmium | 0.49 | 1.11E-07 | 2.06E-07 | 0.001 | 1.11E-04 | 2.06E-04 | | | | | |
| Chromium | 12 | 2.72E-06 | 5.05E-06 | 0.0048 | 5.67E-04 | 1.05E-03 | | | | | |
| Copper | 15 | 3.40E-06 | 6.31E-06 | 0.038 | 8.95E-05 | 1.66E-04 | | | | | |
| Lead[C] | 48 | 1.09E-05 | 2.02E-05 | | | | | | | | |
| Selenium | 0.78 | 1.77E-07 | 3.28E-07 | 0.005 | 3.54E-05 | 6.57E-05 | | | | | |
| Silver | 0.43 | 9.75E-08 | 1.81E-07 | 0.0047 | 2.07E-05 | 3.85E-05 | | | | | |
| Zinc | 57 | 1.29E-05 | 2.40E-05 | 0.33 | 3.92E-05 | 7.27E-05 | | | | | |
| *Others* | | | | | | | | | | | |
| Unionized ammonia | 84 | 1.90E-05 | 3.54E-05 | | | | | | | | |
| Cyanide | 0.37 | 8.39E-08 | 1.56E-07 | 0.0054 | 1.55E-05 | 2.88E-05 | | | | | |
| | | | | **HI** | **0.004229 (child)** | **0.007852 (adult)** | | **Adult Risk** | **2.E-07** | **Child Risk** | **3.E-07** |

References: AECOM 2009, MDEQ 2005a

Acronyms and Abbreviations:

| | | | |
|---|---|---|---|
| CSF | cancer slope factor | RfD | Reference Dose |
| HQ | Hazard Quotient | Sed | sediment |
| PAH | polyaromatic hydrocarbon | VOC | volatile organic compound |
| PNA | polynuclear aromatic compound | | |

Notes:

A. Sediment concentrations given in milligrams per kilogram.

B. Doses are milligrams per day.

C. See "Chemicals Without Adjusted Screening Levels" section for discussion.