Health Consultation

RYERSON CREEK SEDIMENTS
MUSKEGON COUNTY, MICHIGAN

EPA FACILITY ID: MID067340711

AUGUST 23, 2005

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

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HEALTH CONSULTATION

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Prepared by:

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

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Acronyms and Abbreviations

μg	microgram
AE_d	dermal absorption efficiency
AE_i	ingestion absorption frequency
AF	soil adherence factor
AOC	Area of Concern
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
AWRI	Annis Water Resources Institute
CF	conversion factor
DCC	Direct Contact Criteria
DF	age-adjusted soil dermal factor
EF_d	dermal exposure frequency
EF_i	ingestion exposure frequency
EPA	U.S. Environmental Protection Agency
GSI	Groundwater Surface Water Interface Criteria
GSIPC	Groundwater Surface Water Interface Protection Criteria
IEUBK	Integrated Exposure Update Biokinetic Model for Lead in Children
IF	age-adjusted soil ingestion factor
kg	kilogram
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
mg	milligram
NPL	National Priorities List
PAH	polynuclear (or polycyclic) aromatic hydrocarbon
PCB	polychlorinated biphenyl
ppm	parts per million
SF	oral cancer slope factor
TR	target cancer risk
VOC	volatile organic compound

Summary

Ryerson Creek in Muskegon County, Michigan, flows into Muskegon Lake, an area of concern. The Michigan Department of Community Health released a draft public health consultation for this site on June 24, 2005, requesting public comment. No comments were received. Therefore, the consultation has been finalized as initially released.

The creek's sediments contain elevated levels of metals and polynuclear aromatic hydrocarbons. Although the concentrations of the contaminants exceed the state's generic clean-up criteria for residential soils, they do not exceed exposure-adjusted screening levels for the creek's sediments. ***Exposure to the creek's sediments poses no apparent current public health hazard. The future public health hazard is indeterminate.*** If future development occurs along the Muskegon Lake shoreline near the creek's mouth, further characterization and remediation of the sediments may be necessary to prevent exposure to construction workers or future residents.

The creek is prone to flooding during the spring thaw and heavy rains. High flows may have deposited contaminated sediments to floodplain soils. The average arsenic concentration in the soils around the Muskegon Farmer's Market does not exceed the exposure-adjusted screening level calculated for dry soil. As well, the estimated dose of arsenic that a child living at the property in the future might ingest does not exceed the dose found to cause noncancer human health effects. Therefore, ***soil arsenic concentrations in the Farmer's Market area pose no apparent current or future public health hazard.***

The average lead concentration in the soils around Farmer's Market does not exceed the state residential clean-up criterion. However, one sampling location had a high concentration of lead (1,900 ppm [parts per million]). Further sampling at this location is necessary to determine if the high concentration is representative of soil conditions or an anomaly. Therefore, ***soil lead concentrations in the Farmer's Market area pose an indeterminate current and future public health hazard.***

Benzo(a)pyrene concentrations in the soil around Farmer's Market exceed the generic residential criterion but not the exposure-adjusted screening level calculated for that compound. ***Under current use conditions, exposure to benzo(a)pyrene in the soil poses no apparent public health hazard.*** However, if the area is developed, as proposed, for residential use, further characterization of the soil would be necessary. Until that information becomes available, ***the future public health hazard of benzo(a)pyrene concentrations in the soil around Farmer's Market is indeterminate.***

Other public use areas along Ryerson Creek have little or no soil data. However, sediment concentrations upstream of Farmer's Market are not of public health concern. Therefore, ***it is likely that floodplain soils upstream of Farmer's Market have not been impacted by the creek sediments and pose no apparent public health hazard.***

Mercury levels detected in the sediments of and soils near Ryerson Creek pose an indeterminate public health hazard. Although mercury has not been found in

groundwater samples taken near the creek, there are no surface water data to indicate whether or not mercury has entered the creek from the sediments. Mercury is a bioaccumulative chemical that has been found in Muskegon Lake gamefish at levels that could produce human health effects. A Michigan fish advisory in effect for Muskegon Lake recommends that people restrict their consumption of Muskegon Lake fish.

Purpose and Health Issues

On January 19, 2005, the Michigan Department of Environmental Quality (MDEQ) Water Bureau requested assistance in assessing the public health implications of contaminated sediments in Ryerson Creek in Muskegon County. Chemicals of specific concern were arsenic and benzo(a)pyrene. The purpose of this document is to evaluate whether the contaminated sediments in Ryerson Creek, which flows through the city of Muskegon in Muskegon County (Figure 1), pose a health threat to recreational users of the creek and the surrounding area.

Background

Local community groups also have expressed concern regarding the chemicals in the creek sediments. On February 14, 2005, the Michigan Department of Community Health (MDCH) met with approximately 30 people representing local health, government, and neighborhood associations. The meeting took place at the Grand Valley State University Annis Water Resources Institute (AWRI) in Muskegon. The purpose of the meeting was for MDCH to educate the attendants regarding the process of public health consultations, for AWRI to share research findings regarding Ryerson Creek and Little Black Creek (another contaminated creek which is addressed in a separate health consultation), and for the attendants to voice concerns about the contamination.

The source of the creek's contamination is not certain and is likely diverse. There have been several leaking underground storage tanks identified that released gasoline or other solvents, with the resulting contaminated groundwater likely migrating to Ryerson Creek (MDEQ 1995, 1998, 2004a, 2004b). The Farmer's Market area, discussed later in this document, was the site of the city's former incinerator (Superior Environmental Corporation 1996). As well, Ryerson Creek has served as a major storm sewer conveyance, and some of the contamination of the creek may be from urban runoff.

Discussion

Environmental Contamination

Sediments

There has been interest in the contamination of Ryerson Creek since at least the early 1970s (MDNR 1976, 1989). In the late 1970s, the West Michigan Shoreline Regional Development Commission received funding to conduct the Muskegon County Surface Water Toxics Study. In the report summarizing this study, the authors stated that metals, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs) were detected in sediment samples taken at the mouth of Ryerson Creek, by Muskegon Lake (WMSRDC 1982). Some of the chemicals were also found at a sampling site about ½ mile upstream from the mouth (the Farmer's Market area) but at much lower concentrations. Further study, which included more sampling sites, by AWRI in the

1990s resulted in a 1995 document reporting elevated concentrations of metals, total oil and grease, and polychlorinated biphenyls (PCBs) in the creek, primarily near its mouth (Rediske 1995).

The Muskegon Lake watershed has been considered an area of concern (AOC) since 1985 (Muskegon Conservation District 2002). An AOC is defined as a watershed where diminished water quality has caused beneficial use impairments. A multi-agency, locally driven team approach is used to address and remediate AOCs (MDEQ 2002). MDEQ, in conjunction with the Muskegon Lake AOC Public Advisory Committee, local citizens, and AWRI researchers, selected sampling stations in Ryerson Creek and other waterways emptying to Muskegon Lake to determine the extent of contamination (Figure 2). Most of the sampling sites mentioned in the 1982 and 1995 reports cited above were used for this survey as well. Sediment sampling events occurred in December 2002 and April and November 2003. Samples were analyzed for the "Michigan 10" metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc), VOCs, PAHs, PCBs, and pesticides.

As an initial screening tool, MDEQ used the Part 201 Generic Residential and Commercial I Direct Contact Criteria (DCC) to select chemicals requiring further investigation. The residential DCC identifies a soil concentration that is protective against adverse health effects due to long-term (350 days per year for 30 years) incidental ingestion of and dermal exposure to contaminated soil (MDEQ 2001). The criteria are not applicable to the evaluation of contaminated sediments. However, inputs to the algorithm used to calculate the DCC can be adjusted to assist in determining public health implications of exposure to contaminated sediments (Appendix A). This results in an informal, adjusted screening level. The chemicals found in the creek sediments are listed in Table 1, along with the concentrations found, the residential DCC, and the adjusted DCC for those chemicals exceeding the residential DCC.

Table 1. Concentrations of chemicals detected in sediments of Ryerson Creek, Muskegon County, Michigan, and comparison to screening levels. (Samples taken in December 2002 and April and November 2003. All concentrations in parts per million [ppm].)

Chemical	**No. detections / No. samples** [1]	**Concentration Range**	**Residential DCC**[2] **(No. exceedances)**	**Adjusted DCC**[2] **(No. exceedances)**
Metals				
Arsenic	21 / 21	0.26 – 18	7.6 (6)	21 (0)
Cadmium	19 / 21	0.049 – 15	550 (0)	
Chromium	21 / 21	1.1 - 340	2,500 (0)[3]	
Copper	20 / 21	1.3 – 450	20,000 (0)	
Lead	20 / 21	1.5 – 850	400 (3)	See text
Mercury	17 / 21	0.01 – 4.2	160 (0)	
Nickel	21 / 21	0.77 – 110	40,000 (0)	
Zinc	21 / 21	3 – 2,900	170,000 (0)	
PAHs[4]				
Anthracene	1 / 21	2.3	230,000 (0)	
Benzo(a)anthracene	10 / 21	0.57 – 5.1	20 (0)	
Benzo(a)pyrene	6 / 21	0.87 – 4.8	2 (2)	5 (0)
Benzo(b)fluoranthene	6 / 21	0.93 – 7.4	20 (0)	
Benzo(k)fluoranthene	2 / 21	1.3 – 2.7	200 (0)	

Chemical	No. detections / No. samples [1]	Concentration Range	Residential DCC[2] (No. exceedances)	Adjusted DCC[2] (No. exceedances)
Benzo(g,h,i)perylene	1 / 21	2.9	2,500 (0)	
Chrysene	5 / 21	1.8 – 5.5	2,000 (0)	
Dibenzo(a,h)anthracene	1 / 21	1.5	2 (0)	
Fluoranthene	9 / 21	2.1 – 13	46,000 (0)	
Indeno(1,2,3-cd)pyrene	4 / 21	1.1 – 3.8	20 (0)	
Phenanthrene	6 / 21	1.8 – 7	1,600 (0)	
Pyrene	9 / 21	1.6 – 10	29,000 (0)	

Notes: 1. For duplicate samples, only the sample with the higher concentration was counted.
2. DCC = Direct Contact Criteria
3. DCC value is that for hexavalent chromium and is more protective than that for trivalent chromium.
4. PAH = polynuclear aromatic hydrocarbon

Reference: Gannet Fleming 2004

There were no detectable VOCs, PCBs, or pesticides in the sediment samples.

Six sediment samples exceeded the generic DCC for **arsenic** in residential soils but did not exceed the adjusted DCC for that chemical in Ryerson Creek's sediments. Therefore, documented levels of arsenic in the sediments of Ryerson Creek are not a public health concern.

Some sediment concentrations of **lead** exceeded its generic DCC for residential soils. The DCC for lead is determined using the IEUBK model (Integrated Exposure Uptake Biokinetic Model for Lead in Children), which considers other environmental lead sources along with contaminated soil (EPA 2004). Due to the complexity of the model, it is difficult to adjust the DCC for lead in sediments. Therefore, samples containing elevated concentrations of lead are evaluated further in the "Human Exposure Pathways" and "Toxicological Evaluation" sections of this document.

Although sediment **mercury** concentrations did not exceed the generic DCC for residential soils, three samples, representing two sampling locations, exceeded the chemical's MDEQ Groundwater Surface Water Interface Protection Criterion (GSIPC) of 0.1 ppm (comparison not shown in the tables). The GSIPC identifies a soil concentration of a chemical that is not expected to leach and contaminate groundwater at levels greater than the corresponding GSI criterion. The GSI is a groundwater concentration that is protective of a receiving surface water (MDEQ 1999). The GSI for mercury, a bioaccumulative compound, is based on the protection of fish for human consumption.

When mercury is released into surface water, microorganisms change it to methylmercury, a highly toxic form that builds up in fish and, subsequently, in animals that eat fish, including humans. (Fish can also take up the methylmercury directly from the water column but to a much smaller degree when compared to that from the food chain [ATSDR 1999b].) Currently, there is a fish-consumption advisory for Muskegon Lake gamefish (largemouth bass, smallmouth bass, and walleye) based on mercury (MDCH 2004). Mercury concentrations in the Ryerson Creek sediments may contribute to a human health hazard via ingestion of gamefish from Muskegon Lake.

The sediment samples from Ryerson Creek that exceeded the mercury GSIPC were located at RYC-1 (two samples at different depths exceeding the criterion) and RYC-3, next to Farmer's Market (see Figure 2). There are no surface water data available for the creek. Therefore, it is not known if mercury might be entering Ryerson Creek via the contaminated sediments. As well, it is not known what proportion, if any, the mercury in the creek sediments might contribute to mercury concentrations in fish from Muskegon Lake.

Although two **benzo(a)pyrene** concentrations exceeded the generic DCC for residential soils, they did not exceed the adjusted DCC for that chemical in Ryerson Creek's sediments. Therefore, documented levels of benzo(a)pyrene in the sediments of Ryerson Creek are not a public health concern.

AWRI researchers used several of the sediment samples from the 2002 and 2003 sampling for **sediment toxicity testing** on benthic organisms. The test results indicated that sediment contamination was affecting mortality and growth of the organisms (Gannett Fleming 2004, Rediske 2004). The areas of toxicity in the creek were near the mouth and by Farmer's Market. While adverse impacts on aquatic organisms have been demonstrated by this testing, the results are not directly applicable to the evaluation of public health implications.

Soils

Community members expressed concern that occasional flooding of Ryerson Creek could lead to transfer of contamination to nearby soils. Soil sampling near the creek occurred in August and September 1996, next to the Muskegon Farmer's Market (near RYC-3 and RYC-4 in Figure 2; see Figure 3 for soil sampling locations). Twelve 6-inch-deep samples were collected, and 15 samples were collected at depths from 1 to 8 feet. The samples were analyzed for the "Michigan 10" metals, VOCs, PAHs, PCBs, and formaldehyde. Analytical results were first compared to the generic Part 201 DCC for residential soils, which assumes an exposure frequency of 350 days per year. The market is seasonal and only open May through December (approximately 35 weeks), three to four days per week. Therefore, the screening levels for chemicals exceeding their residential DCC were adjusted to allow for an exposure frequency of 74 days per year (Appendix B). The chemicals found in the soil by Farmer's Market are listed in Table 2, along with the concentrations found, the residential DCC, and the adjusted DCC for those chemicals exceeding the generic DCC.

Table 2. Concentrations of chemicals detected in soils near Farmer's Market, Muskegon County, Michigan, and comparison to screening levels. (Samples taken in August and September 1996. All concentrations in parts per million [ppm].)

Chemical	**Soil Depth (feet)**	**No. detections / No. samples**	**Concentration Range**	**Residential DCC[1] (No. exceedances)**	**Adjusted DCC[1] (No. exceedances)**
Metals					
Arsenic	0.5	12 / 12	0.41 - 31	7.6 (5)	25 (2)
	1-8	15 / 15	0.36 – 3.1	7.6 (0)	
Barium	0.5	12 / 12	11 – 450	37,000 (0)	
	1-8	15 / 15	5.1 – 600	37,000 (0)	
Cadmium	0.5	11 / 12	0.26 – 3.5	550 (0)	
	1-8	13 / 15	0.06 – 4	550 (0)	
Chromium	0.5	12 / 12	4.4 – 60	2,500 (0)[2]	
	1-8	15 / 15	1.6 –220	2,500 (0)	
Copper	0.5	12 / 12	1.2 – 460	20,000 (0)	
	1-8	15 / 15	1.4 – 240	20,000 (0)	
Lead	0.5	12 / 12	5.4 – 1,900	400 (2)	See text
	1-8	15 / 15	34 – 750	400 (1)	See text
Mercury	0.5	3 / 12	0.25 – 0.5	160 (0)	
	1-8	5 / 15	0.11 – 0.88	160 (0)	
Selenium	0.5	4 / 12	0.53 – 1	2,600 (0)	
	1-8	0 / 15	---	2,600 (0)	
Silver	0.5	1 / 12	4.4	2,500 (0)	
	1-8	6 / 15	0.6 – 2.1	2,500 (0)	
Zinc	0.5	12 / 12	5.7 – 1,200	170,000 (0)	
	1-8	15 / 15	4.2 - 970	170,000 (0)	
VOCs[3]					
Ethylbenzene	1-8	1 / 2	0.026	140 (0)	
Methylene chloride	1-8	2 / 2	0.011 – 0.036	1,300 (0)	
Xylenes	1-8	1 / 2	0.09	150 (0)	
PAHs[4]					
Acenaphthene	0.5	1 / 8	0.34	41,000 (0)	
	1-8	0 / 7	---	41,000 (0)	
Acenaphthylene	0.5	1 / 8	1.3	1,600 (0)	
	1-8	0 / 7	---	1,600 (0)	
Anthracene	0.5	1 / 8	2	230,000 (0)	
	1-8	0 / 7	---	230,000 (0)	
Benzo(a)anthracene	0.5	2 / 8	0.72 – 6.7	20 (0)	
	1-8	1 / 7	0.44	20 (0)	
Benzo(a)pyrene	0.5	2 / 8	0.61 – 6.1	2 (1)	6 (0)
	1-8	1 / 7	0.45	2 (0)	
Benzo(b)fluoranthene	0.5	2 / 8	0.9 – 8.6	20 (0)	
	1-8	1 / 7	0.6	20 (0)	
Benzo(k)fluoranthene	0.5	1 / 8	3.2	200 (0)	
	1-8	0 / 7	---	200 (0)	
Benzo(g,h,i)perylene	0.5	1 / 8	3.2	25,000 (0)	
	1-8	0 / 7	---	25,000 (0)	
Bis(2-ethylhexyl)phthalate	1-8	2 / 7	0.35 – 0.71	28,000 (0)	

Chemical	Soil Depth (feet)	No. detections / No. samples	Concentration Range	Residential DCC[1] (No. exceedances)	Adjusted DCC[1] (No. exceedances)
Chrysene	0.5	2 / 8	0.66 – 6.1	2,000 (0)	
	1-8	1 / 7	0.45	2,000 (0)	
Dibenzo(a,h)anthracene	0.5	1 / 8	1.1	2 (0)	
	1-8	0 / 7	---	2 (0)	
Fluoranthene	0.5	2 / 8	1.3 - 13	460,000 (0)	
	1-8	2 / 7	0.67 – 1.5	460,000 (0)	
Fluorene	0.5	1 / 8	0.5	270,000 (0)	
Indeno(1,2,3-cd)pyrene	0.5	1 / 8	3.7	20 (0)	
	1-8	0 / 7	---	20 (0)	
2-Methylnaphthalene	0.5	3 / 8	0.41 – 1.6	81,000 (0)	
	1-8	1 / 7	0.92	81,000 (0)	
Naphthalene	0.5	1 / 8	1.5	160,000 (0)	
	1-8	0 / 7	---	160,000 (0)	
Phenanthrene	0.5	3 / 8	0.35 – 6.3	16,000 (0)	
	1-8	2 / 7	0.42 – 1.1	16,000 (0)	
Pyrene	0.5	2 / 8	1.3 - 12	290,000 (0)	
	1-8	2 / 7	0.59 – 1.2	290,000 (0)	

Notes:

1. DCC = Direct Contact Criteria
2. DCC value is that for hexavalent chromium and is more protective than that for trivalent chromium.
3. VOC = volatile organic compound
4. PAH = polynuclear aromatic compound

Reference: Superior Environmental Corporation 1996

There were no detectable PCBs or formaldehyde in the samples analyzed for these compounds.

Two soil samples exceeded the adjusted DCC for **arsenic** (for occasional contact with contaminated soils). The magnitude of the exceedances is not great (less than double the adjusted DCC); however, the samples are evaluated further in the “Human Exposure Pathways” and “Toxicological Evaluation” sections of this document.

Some concentrations of **lead** exceeded its generic DCC for residential soils. The DCC for lead is determined using the IEUBK model (Integrated Exposure Uptake Biokinetic Model for Lead in Children), which considers other environmental factors beside contaminated soil (EPA 2004). Due to the complexity of the model, it is difficult to adjust the DCC for lead to address occasional contact with contaminated soils. Therefore, samples containing elevated concentrations of lead are evaluated further in the “Human Exposure Pathways” and “Toxicological Evaluation” sections of this document.

Although **mercury** concentrations did not exceed the residential DCC, eight soil samples exceeded the chemical’s MDEQ GSIPC of 0.1 ppm. Groundwater sampled at Farmer’s Market did not have detectable amounts of mercury in it (Superior Environmental Corporation 1996), indicating that groundwater has not been impacted. Although sediments in the creek also exceeded the GSIPC for mercury, as discussed earlier in this document, there are no surface water data to indicate whether or not mercury has entered Ryerson Creek and could be impacting fish concentrations.

Although one **benzo(a)pyrene** concentration exceeded the generic DCC for residential soils, it did not exceed the adjusted DCC (for occasional contact with contaminated soil). Therefore, documented levels of benzo(a)pyrene in the soils near Farmer's Market are not a public health concern when considering current use of the property. However, if the property is developed for future residential use, the residential DCC would apply and further characterization of the soil would be necessary to determine the risk to public health.

Human Exposure Pathways

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: (1) a source of contamination, (2) contaminant transport through an environmental medium, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population. An exposure pathway is considered complete if 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 no evidence that at least one of the elements above are, have been, or will be present, or that there is a lower probability of exposure. The exposure pathway elements for this site are shown in Table 3:

Table 3. Pathways of human exposure to contaminants found in sediments in Ryerson Creek, Muskegon County, Michigan.

Source	**Environ-mental Transport and Media**	**Chemicals of Concern**	**Exposure Point**	**Exposure Route**	**Exposed Population**	**Time Frame**	**Status**
Ryerson Creek sediments	Sediment	Metals, PAHs[1]	Creek sediment	Dermal contact, incidental ingestion	Recreational users of Ryerson Creek	Past	Complete
						Present	Potential
						Future	Potential
	Fish and other aquatic wildlife	Mercury	Ryerson Creek, Muskegon Lake	Ingestion	Consumers of fish and other aquatic species	Past	Complete
						Present	Potential
						Future	Potential
	Sediment	Metals, PAHs	Flood-plain soils	Dermal contact, incidental ingestion, inhalation	Persons living along or using the creek's floodplain	Past	Potential
						Present	Potential
						Future	Potential

Notes:

1. PAHs = polynuclear aromatic hydrocarbons

Sediments

Anecdotal evidence indicates that area children regularly played in Ryerson Creek (EnviroMich 2004), indicating a completed past exposure pathway. It is unknown to what extent people may enter the creek now.

Persons wading or playing in the creek could be exposed to the contaminated sediments. However, as discussed in the "Environmental Contamination" section of this document, the only chemical of concern in regard to dermal contact with the sediments is **lead**. The locations in which the exceedances of the generic lead DCC for residential soils occurred were RYC-1 (2-4 feet sediment depth) and RYC-2 (2-4 feet and 4-6 feet sediment depths) (Figure 2). A person is not likely to be standing at these depths in the sediment. Additionally, these locations are at the mouth of the creek in Muskegon Lake. Photographs of the sampling location (Figure 4), along with a map of the area (Figure 2), indicate that these locations are in an industrialized part of the city of Muskegon and likely off-limits to the general public. Therefore, excessive exposure to lead in the sediments is not likely to occur under current conditions, and no adverse health effects are expected.

Figure 4. Area near RYC-1 and RYC-2 sampling locations, Muskegon Lake at the mouth of Ryerson Creek. (Gannet Fleming 2004)

People could be exposed to the lead in the sediments near the mouth of Ryerson Creek in the future. The Muskegon Lake shoreline south of the creek's mouth is expected to be redeveloped into a commercial and residential area called "Edison Landing" (Lakefront Development LLC 2005). Residents whose property abuts the lakefront may wade in the lake and could be exposed to contaminated sediments. Construction workers could be exposed to sediments near or on the shore. It is not clear whether development plans include dredging sediments in this area.

Fish and Other Aquatic Wildlife

The **mercury** in the sediments in Ryerson Creek might be exacerbating conditions in Muskegon Lake fish. According to the 2000 U.S. census, about 20 percent of the population of the City of Muskegon lives below the poverty level (GeoLytics, Inc. 2002). Although fish advisories exist for Muskegon Lake, economically disadvantaged persons might ignore them and fish in the lake to supplement their diet, potentially exposing themselves to mercury in the fish.

Anecdotal evidence indicates that the area of the creek near Farmer's Market contains turtles (T. Berdinski, MDEQ Water Bureau – Grand Rapids Office, personal communication, 2005). During a site visit in April 2005, MDCH staff noticed a muskrat feeding next to the creek near Farmer's Market. Painted turtles and muskrat, though primarily herbivorous, occasionally eat fish (National Wildlife Federation 2005) and may bioaccumulate methylmercury. Snapping turtles eat both aquatic plants and animals (National Wildlife Federation 2005) and would likely bioaccumulate methylmercury. Economically disadvantaged populations might supplement their diet by catching and eating turtles and muskrat from the creek and could be exposed to mercury in these animals. However, there is no information regarding contaminant levels in these species in this area nor to what extent local persons may eat them.

Floodplain Soils

Community members claim that Ryerson Creek can overflow its banks during the spring thaw and heavy rains. Contaminated sediments might be transferred to soil during these overflows. If flooding occurs in areas normally used by the public, the likelihood and frequency of exposure would increase.

The only substantial soil data available for areas around Ryerson Creek are for the Farmer's Market area, near sampling sites RYC-3 and RYC-4. The market is open from May to December, three days a week (Tuesdays, Thursdays, and Saturdays). The site also hosts a flea market, open Wednesdays, May to October. Vendors at the market would likely frequent the site the most; however, they would be attending their stalls and would not likely be exposed to the floodplain soils. Customers would not likely be exposed to the floodplain soil as well; however, their children or the vendors' children might play near the creek while waiting for their parents. The estimated maximum number of days a child would be exposed to the floodplain soils is 74 (four days per week during the 13 weeks of summer break, and one day per week during the other 22 weeks of the market season). This exposure estimate was used when adjusting the residential DCC for arsenic in the soil at Farmer's Market to 25 ppm (Appendix B). Assuming that children would use the entire area and not just one spot while visiting the market, their degree of exposure would be averaged. The average **arsenic** concentration in the 12 shallow soil samples at the market was 8.5 ppm, less than the adjusted DCC (addressing occasional contact with contaminated soil), and therefore is not of concern when considering current use of the area.

The average **lead** concentration in the 12 shallow soil samples from the market was 335 ppm, less than the generic DCC for that metal in residential soils. Two samples exceeded the residential DCC. One exceedance (sample SB-10) was 600 ppm, less than double the criterion, and of less concern than the other exceedance (sample SB-16), which was 1,900 ppm (Figure 3). (This sample had the highest concentration of several of the metals tested.) Further characterization of the area around SB-16 is necessary to determine whether the concentration is an anomaly or indeed representative of soil lead concentrations in that location.

Exposure to **benzo(a)pyrene** in the soils at Farmer's Market should not result in adverse health effects, under current exposure assumptions, since the concentrations found do not exceed the exposure-adjusted screening level for that compound.

The City of Muskegon is planning on moving the market elsewhere, with hopes that the current site will be developed for single-family homes (Burns 2005a,b). If the site becomes residential, the generic DCC for **arsenic** in residential soils (7.6 ppm) would apply. A child living at this site in the future would not necessarily be exposed to the average overall concentration but, more likely, to the concentration specific for the property lot on which the child's home is situated. The concentration of arsenic on an individual residential lot might be greater than the residential DCC. However, it is likely that development of the site will include bulldozing and excavating as well as bringing in clean fill, diluting the arsenic concentrations.

Similarly, most of the soil **lead** concentrations also would be diluted by development activities. Sample SB-16, however, was taken near the creek edge (Figure 3) and would likely remain undisturbed. Children living near this sampling location in the future might be exposed to high concentrations of lead in the soil on a regular basis and suffer adverse health effects. The area around SB-16 should be characterized further to determine whether the concentration found there is an anomaly or indeed representative of soil lead concentrations in that location.

The location of the soil sample that exceeded the residential DCC for **benzo(a)pyrene** (SB-13) is located near a road (Figure 3). It is possible that this specific location will not be incorporated into a future residential lot but instead be a public sidewalk or green space. Also, development activities would likely remove or reduce the contamination. Nevertheless, the area around this location should be characterized further, taking into consideration the planned future use of the location, to determine any remedial steps necessary to protect the public health.

The majority of the soil samples taken in the Farmer's Market area were from the south side of Ryerson Creek (Figure 3), where the market is situated. The north side of the creek, known as Green Acres Park, sits at a lower elevation and therefore is more likely to flood than is the south side. (Due to the higher elevation of the south side of the creek, it is more likely that contaminants in the soil in that area are from the former incinerator on the property than from the creek's sediments.) Although Green Acres Park does not appear to be used for market activities, there are some old play structures (monkey bars, baseball diamond) that could still be in use. The two soil samples taken from the park did not exceed the residential DCC for any chemicals tested, suggesting that the soil poses no public health threat under current use conditions. However, it is not known what future use this site may receive. If, like Farmer's Market, it is to be developed for residential use, further characterization of the soils may be necessary to ensure that individual plots do not pose a health hazard. However, it is likely that construction activities would dilute or remove as-yet unknown areas with high concentrations.

Smith-Ryerson Park, where sediment sample RYC-6 was taken, is another public use area along Ryerson Creek that is prone to flooding, but it has limited soil data. In June 2001, a sanitary sewer break occurred along Wood Street near where it crosses the creek. Follow-up soil sampling for metals, VOCs, and SVOCs at locations near the road, including one sample taken in the park, indicated that minimal contamination remained once the wastewater receded (data not shown) (WMS 2001). A single sample normally may not be sufficient in determining whether sediments have impacted floodplain soils. However, Ryerson Creek sediment data for the area upstream of Farmer's Market, which includes Smith-Ryerson Park, indicate that the concentrations in the sediment are not of public health concern. Therefore, it is likely that the floodplain soils upstream of Farmer's Market have not been impacted and are not of public health concern either.

It is unknown what areas of Ryerson Creek may flood onto adjacent private residential properties. Therefore, it is not known if exposure pathways exist on residential properties bordering the creek. It could be expected, however, that if local sediments do not exceed the residential DCC for the chemicals tested, neighboring floodplain soils may not exceed the criteria either.

Toxicological Evaluation

Arsenic

Arsenic is a naturally occurring element. Inorganic arsenic compounds have been used as wood preservatives (treated or "Wolmanized" lumber), but that application is no longer practiced. Organic arsenic compounds have been used as pesticides, primarily on cotton plants (ATSDR 2000).

Dermal (skin) exposure to high levels of arsenic may lead to irritation of the skin. Severe skin effects have only been observed in workplaces that have high levels of arsenic dusts. The effects have not been noted in people exposed to arsenic in water or soil, likely because the concentrations in these media would be much lower than in dusty occupational settings (ATSDR 2000).

The most common sign of long-term oral (eating) or inhalational (breathing) exposure to low levels of inorganic arsenic is a darkening of the skin and the appearance of small corns or warts on the palms, soles, and torso. These symptoms were seen at doses of 0.01-0.02 milligrams of arsenic per kilogram body weight per day (mg/kg/day) (ATSDR 2000). For health risk assessment purposes, it is assumed that a child weighing 10 kg will eat 200 mg of soil per day (2E-4 kg, which is less than 1/8 teaspoon). If a child were to eat 200 mg of soil containing 31 parts per million (ppm, which equals mg/kg) arsenic, the maximum concentration found in the Ryerson Creek area, the daily dose of arsenic for that child would be 0.00062 mg/kg/day.

$$\frac{2E-4kg_{Soil}/day}{10kg_{BW}} \times \frac{31mg_{Arsenic}}{1kg_{Soil}} = 0.00062mg_{Arsenic}/kg_{BW}/day$$

An adult would eat less soil per day (100 mg/day) and weigh more (70 kg) than a child, resulting in a lower dose (0.000044 mg/kg/day). No skin effects would be expected in a child or adult who ingested arsenic-contaminated soil from the Ryerson Creek area.

Other symptoms of long-term exposure to arsenic include an abnormal heart rhythm, nausea and vomiting, and a sensation of “pins and needles” in the hands and feet. Arsenic also has been identified as a known human carcinogen. Since the most common health effect of dermal changes is not expected, other adverse effects would likely not occur.

Lead

Like arsenic, lead is a naturally occurring element. It is used in a number of occupational settings and by hobbyists. Sources for lead exposure include battery manufacture and repair, plumbing, pipe fitting, jewelry and pottery making, stained glass making, emissions from foundries and smelters, and some imported or folk remedies. Lead was used in residential paint before its use was discontinued in 1978 (ATSDR 1999a).

Lead is well-known for its neurotoxic effects, causing learning and behavioral difficulties in children. Nervous system effects in adults include decreased reaction times, weakness in the hands and ankles, and impaired memory. It can also damage the kidneys, the reproductive system, and cause anemia. Rather than an external dose in mg/kg/day, the level of lead in the body, usually expressed as blood levels, is used to determine the potential for adverse health effects. This approach is used because exposure can occur from several different sources including air, food, water, and soil contamination. Models that account for multiple exposures to lead often are used to assess potential effects from exposure to lead in the environment (ATSDR 1999a). As discussed earlier in the “Environmental Contamination” section of this document, the criterion for lead in soil is based on the IEUBK model. All potential sources of lead must be evaluated to determine if the contribution from contaminated sediment or soil is significant. Most often, lead-based paint in older homes is the most important source of lead in a person’s environment. In the City of Muskegon, 50 percent of the homes were constructed before the 1950s, when the lead in paint was at its highest concentration, and 92 percent of the homes were constructed before the 1980s (GeoLytics 2002), before lead use in residential paint was discontinued. Due to the level of poverty in the City of Muskegon (20 percent of the population lives below the poverty level [GeoLytics 2002]), it is likely that many of these homes have not had the paint removed or sealed. Therefore, it is possible that people living near Ryerson Creek are experiencing multiple exposures to lead and could exhibit symptoms of lead poisoning.

The National Toxicology Program recently reported that lead may be “reasonably anticipated to be a human carcinogen” (NTP 2004). This determination was based on limited evidence in human studies and sufficient evidence in animal studies. The human studies investigated occupational settings in which workers primarily were exposed via inhalation (NTP 2004). Exposure to the lead in Ryerson Creek sediments and nearby soils would likely occur primarily through ingestion. It is unknown whether oral exposure has as great a cancer risk as inhalation exposure.

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. Methylmercury, an organic mercury compound, is formed by bacteria in soil or water where airborne mercury compounds have deposited. Methylmercury builds up in the aquatic food chain, with higher concentrations being found in predator fish (ATSDR 1999b).

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 1999b). The levels of mercury in the sediments of Ryerson Creek are not great enough to cause these effects.

Dermal exposure to and unintentional ingestion of the sediments or soils containing mercury should not result in any harm. It is not likely that the mercury could volatilize (enter the air) and be inhaled. The exposure pathway of concern for mercury in the Ryerson Creek area is that of ingesting contaminated fish. As discussed earlier in the "Environmental Contamination" section of this document, Ryerson Creek empties into Muskegon Lake, which is under a fish-consumption advisory for mercury in several gamefish species (largemouth bass, smallmouth bass, walleye) (MDCH 2004). Persons eating these species or other potentially contaminated aquatic wildlife (turtles, muskrat) from either the lake or Ryerson Creek might be at risk of methylmercury toxicity. It is likely that toxic effects would not manifest themselves immediately but build up over time and appear insidiously. However, as discussed earlier in this document, it is not known whether mercury in the creek sediments have entered the creek itself, as there are no surface water data.

Benzo(a)pyrene

Benzo(a)pyrene belongs to a group of chemicals called polynuclear (or polycyclic) aromatic hydrocarbons (PAHs). These chemicals are formed during incomplete combustion processes. They are found in vehicle and stack emissions, cigarette smoke, and grilled meat. PAHs occur in the environment as mixtures. Formulations of PAH mixtures have been used to treat skin disorders (e.g., pine tar shampoo for psoriasis) (ATSDR 1995).

Dermal exposure to PAHs may result in skin irritation, dermatitis, and photosensitization. Inhalation of PAHs, such as via cigarette smoking, can lead to lung cancer. Exposure to PAH mixtures can cause cancer induction, although no direct link has been found to individual compounds (ATSDR 1995).

Exposure to benzo(a)pyrene in the Farmer's Market soils should not result in adverse health effects, under current exposure assumptions. However, the contamination should be addressed if the area is developed for residential use, to lessen the risk of exposure and adverse health effects.

Children's Health Considerations

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. Even before birth, children are forming the body organs they need to last a lifetime. Injury during key periods of 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 obvious implication for environmental health is that children can experience substantially greater exposures to toxicants in soil, water, or air than adults can.

It is not known if children are more susceptible to the effects of arsenic exposure than adults are. However, as discussed in the "Toxicological Evaluation" section of this document, it is unlikely that a child would be exposed to sufficient levels of arsenic in the soils around Ryerson Creek to cause the skin effects identified as the most common health effect.

Young children, especially those from urbanized, low-income populations, are at the greatest risk for experiencing lead-induced health effects. Children under 5 years old absorb lead from the gastrointestinal tract more efficiently than do adults (about 50% versus 15% relative absorption, respectively). Thumb-sucking and pica behavior (consuming large quantities of non-food items) can increase the amount of lead-contaminated dust and dirt being transferred to the gastrointestinal tract. Deficits in some nutrients, including calcium, iron, and zinc, can exacerbate the toxic effects of lead. Lead can pass through the placenta to a developing fetus and can be secreted through breast milk (ATSDR 1999a). When considering the effects that lead in the soils around Ryerson Creek might have on children's health, one should also consider and address other sources of lead so that overall exposure is minimized.

Very young children are more sensitive to mercury than are adults. Mercury in the mother's body passes to the fetus and may accumulate there. It can also pass to a nursing infant through breast milk. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage (ATSDR 1999b). Mercury levels in the sediments of Ryerson Creek might be contributing to elevated mercury in Muskegon Lake fish. MDCH fish advisories recommend that women of childbearing age and children under the age of 15 limit their consumption of Muskegon Lake bass and walleye to one or fewer meals per month because of the mercury levels found in these species (MDCH 2004).

Community Health Concerns

During the February 14, 2005 meeting, a local resident expressed concern that several school science classes would enter Ryerson Creek as part of the lessons regarding environmental and ecological systems. MDCH contacted the superintendent for Muskegon Schools for information regarding which schools and classes used the creek for field studies. Reportedly, only the science laboratory at Steele Middle School conducted water-testing exercises. The science teacher would enter a gully, not the creek itself, to collect water samples. Students did not enter the water (J. Schulze, Muskegon Public Schools, personal communication, 2005). If school classes or other educational groups, such as scout troops, enter Ryerson Creek, the occasional nature of any exposure to chemicals in the sediments is not likely to result in adverse health effects.

Other persons asked whether high flow events or scouring by ice in the winter could cause areas of contamination to be moved downstream, resulting in newly contaminated sections of Ryerson Creek. This is a possibility. However, the available data indicate that the contamination that would be of potential public health concern starts at the Farmer's Market area and goes to the mouth of the creek in Muskegon Lake. The area around this stretch of the creek is primarily industrial and not easily accessed, except at Green Acres (on the north side of the creek from Farmer's Market). Current exposure assumptions suggest exposure is minimal and has no negative public health implications. If the contamination were to move downstream from Farmer's Market, exposure would still be minimal and adverse health effects would not be expected. If the Farmer's Market and Green Acres properties are developed for residential use, further characterization of the sediments and soils might be necessary. However, it is likely that construction activities would dilute or remove the contamination.

On April 18, 2005, the Muskegon Lake Public Advisory Council met with local residents to discuss current and historic uses of Ryerson Creek and areas adjacent to it. This discussion resulted in a list of potential pollution sources to the creek that should be investigated further by local and state regulatory agencies. Anecdotal evidence suggests that there may have been illicit dumping or unreported releases to Ryerson Creek or nearby soils.

On June 24, 2005, MDCH issued a draft public health consultation addressing exposure to the creek's sediments. The agency invited public comment on the document; however, no comments were received.

Conclusions

Although the concentrations of arsenic and benzo(a)pyrene in the sediments of Ryerson Creek exceed the MDEQ generic Part 201 clean-up criteria for residential soils, they do not exceed exposure-adjusted screening levels addressing contact with sediments. High lead concentrations were found only in deep sediments that likely are not accessible to the public. Therefore, ***exposure to the creek's sediments poses no apparent current public health hazard***. If the Muskegon Lake shoreline near the mouth of Ryerson Creek is developed, as proposed, into Edison Landing, ***the future public health hazard of***

exposure to the sediments in this area is indeterminate. Further characterization and remediation of the sediments may be necessary to prevent exposure to construction workers or future residents.

The average soil arsenic concentration in the soils around Farmer's Market does not exceed the exposure-adjusted screening level addressing occasional contact. The estimated dose of arsenic that a child living at the property in the future might ingest does not exceed the dose found to cause noncancer human health effects. Therefore, ***soil arsenic concentrations in the Farmer's Market area pose no apparent current or future public health hazard.***

The average lead concentration in the soils around Farmer's Market does not exceed the generic clean-up criterion for residential soils. However, the soil at sampling location SB-16 should be characterized further to determine if the high concentration found there (1,900 ppm) is an anomaly or truly representative of the soil in that area. Therefore, ***soil lead concentrations in the Farmer's Market area pose an indeterminate public health hazard.***

The benzo(a)pyrene concentrations in the soils around Farmer's Market do not exceed the exposure-adjusted screening level for addressing occasional contact. If the area is developed for residential use, further analysis would be needed to determine any public health implications. ***There is no apparent public health hazard posed by the benzo(a)pyrene in the soil, under current use, but the future public health hazard is indeterminate.***

Creek sediments likely have not impacted floodplain soils upstream of the Farmer's Market area. Therefore, ***floodplain soils upstream from the market area pose no apparent public health hazard.***

Mercury detected in the sediments of the creek might be exacerbating mercury concentrations in Muskegon Lake fish as well as other aquatic wildlife if the contamination is entering the water column. Until that information is available, ***mercury in the sediments of Ryerson Creek area pose an indeterminate public health hazard.*** A Michigan fish consumption advisory based on mercury in gamefish species is in effect for the lake.

Recommendations

1. Characterize further and remediate as necessary contaminated sediments near the mouth of Ryerson Creek, especially in the area slated to be developed into Edison Landing.
2. Characterize further and remediate as necessary contaminated soil in the Farmer's Market area.
3. Educate local residents about sources of lead and how to prevent exposure.
4. Maintain the current fish consumption advisory for Muskegon Lake.
5. Investigate potential pollution sources to Ryerson Creek that may impact public health.

Public Health Action Plan

1. The City of Muskegon and other responsible parties will develop, with MDEQ oversight, sampling plans and remediation efforts in the future Edison Landing area, the Farmer's Market area, and other sites of known contamination. (The MDEQ divisions responsible for specific areas include: the Water Bureau, addressing water and sediments; and the Remediation and Redevelopment Division, addressing land clean-up and leaking above-ground or underground storage tanks.)
2. The Muskegon County Health Department, with assistance from MDCH, will provide information to local residents regarding lead exposure.
3. MDCH will maintain, and update as necessary, the fish consumption advisory, based on fish data collected by the MDEQ Fish Contaminant Monitoring Program.
4. MDEQ will continue meeting with local government and environmental groups and investigate potential sources of pollution to Ryerson Creek and adjacent soils as evidence indicates. (See first step regarding MDEQ division responsibilities.)

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 the Michigan Department of Community Health, Division of Environmental and Occupational Epidemiology, at 1-800-648-6942.

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Figures (3)

Appendix A. Adjustment of MDEQ Residential Direct Contact Criteria to Address Contact with Contaminated Sediments in Ryerson Creek

The purpose of the MDEQ Generic Residential and Commercial I Direct Contact Criteria (DCC) is to protect against adverse health effects due to long-term ingestion of and dermal exposure to contaminated soil. The generic DCC are only protective of chronic, not acute, effects and do not address inhalation of any volatile chemicals. The generic DCC may be adjusted to address the protection of persons who may come into contact with contaminated sediments, such as by wading or playing in Ryerson Creek. The following discussion will demonstrate how the criteria were adjusted to account for a person standing in the creek. To be protective, MDCH assumed that a person would have exposure to the creek and its sediments from childhood through adulthood.

Arsenic is a known human carcinogen (EPA 1998). Benzo(a)pyrene is a probable human carcinogen (EPA 1994). The equation used to determine the Residential DCC of a known or probable carcinogen is below (MDEQ 2001):

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

TR is the target cancer risk, or the acceptable risk. An "acceptable" risk may range from 1 in 10,000 to 1 in 1,000,000, meaning that no more than one additional person in ten thousand (1E-4) or one million (1E-6) persons who are exposed to a specific carcinogen will die from cancer compared to a similar population not exposed to the carcinogen. The target risk in this exercise is set at 1 in 100,000 (**1E-5**).

AT is the averaging time factor, which, for carcinogens, is equivalent to the average human lifespan of 70 years, or **25,550 days**. When a chemical is found to be carcinogenic in laboratory animals, the research typically involves a high dose of the chemical given to the animal over a short period of time. Based on the assumption that a high dose of a carcinogen received over a short period of time is equivalent to a corresponding low dose spread over a lifetime, human exposures are calculated by prorating the total cumulative dose over an average person's lifetime.

CF is the conversion factor used so that the appropriate units appear in the product of the equation. This factor is equal to 1,000,000,000 micrograms per kilogram (**1E+9 µg/kg**).

SF is the oral cancer slope factor, which is an estimate of the increased cancer risk from a lifetime exposure to a chemical. It is a probability estimate that is used only for comparative purposes. It is not a predictive tool. The SF for arsenic is 1.5 per milligram per kilogram-day [**1.5 (mg/kg-day)$^{-1}$**] (EPA 1998). The SF for benzo(a)pyrene is **4.1 (mg/kd-day)$^{-1}$** (EPA 1994).

EF_i is the ingestion exposure frequency. It is assumed in this exercise that a child or adult would be exposed to the sediment in the creek **90 days** (3 months) per year.

IF is the age-adjusted soil ingestion factor. It assumes that a child through the age of six years eats 200 mg of soil per day, and that an adult will eat 100 mg of soil per day for 24 years. Each ingestion total (years X amount eaten/year) is divided by the respective default body weight and the resulting quotients are summed. In this exercise, the ATSDR default child body weight of 10 kg was used rather than the EPA default of 15 kg, to provide greater protection. Therefore, IF in this exercise is equal to **154 mg-year/kg-day**.

AE_i is the ingestion absorption efficiency (a science-based estimate of what percentage of a chemical is absorbed through the gastrointestinal tract) and is chemical-specific. For both arsenic and benzo(a)pyrene, the AE_i is **0.5** (50 percent) (MDEQ 2003).

EF_d is the dermal exposure frequency. Similar to EF_i above, it is assumed that a person would be exposed to the sediment in the creek no more than **90 days** per year.

DF is the age-adjusted soil dermal factor. It considers exposed skin surface area, a soil adherence factor (AF), number of events per day, and the exposure duration and divides the product of those factors by the body weight. Respective subfactors are determined for a child and an adult and then summed. The default AF for children is 0.2 milligrams per square centimeter (mg/cm^2), meaning 0.2 mg of soil would adhere to each square centimeter of exposed skin (MDEQ 2001). The default AF is applicable to the 95^{th} percentile of children playing in *dry* soil (95 percent of children would have less soil adhering). In this case, however, the creek sediments would be wet and likely adhere more readily than dry soil. Conversely, a child or adult would likely rinse off the majority of the sediment when coming out of the creek. An AF value of 0.2 mg/cm^2 also applies to the *50^{th}* percentile of children playing in *wet* soil. This value affords some protection against adhered sediments, even though the majority, if not all, of the sediment would be washed off. Similar to the IF above, MDCH used the ATSDR default child body weight of 10 kg when calculating the DF. No adjustments were made for the adult subfactor. The DF in this exercise is equal to **459.6 mg-year/kg-day**.

AE_d is the dermal absorption efficiency (a science-based estimate of what percentage of a chemical is absorbed through the skin) and is chemical-specific. The value for arsenic is **0.03** (3 percent). The value for benzo(a)pyrene is **0.13** (13 percent).

The adjusted Residential DCC for arsenic is calculated as follows:

$$Adjusted\ ResidentialDCC_{Arsenic} = \frac{1E-5 \times 25{,}550 \times 1E+9}{1.5[(90 \times 154 \times 0.5) + (90 \times 459.6 \times 0.03)]}$$

$$Adjusted\ ResidentialDCC_{Arsenic} = 20{,}846\ \mu g/kg = 21 mg/kg$$

The units mg/kg are equivalent to parts per million (ppm).

The adjusted Residential DCC for benzo(a)pyrene is calculated as follows:

$$Adjusted\ Residential DCC_{Benzo(a)pyrene} = \frac{1E-5 \times 25{,}550 \times 1E+9}{4.1[(90 \times 154 \times 0.5) + (90 \times 459.6 \times 0.13)]}$$

$$Adjusted\ Residential DCC_{Benzo(a)pyrene} = 5{,}063\,\mu g/kg = 5 mg/kg$$

Appendix B. Adjustment of MDEQ Residential Direct Contact Criteria to Address Occasional Contact with Contaminated Soils next to Ryerson Creek

The purpose of the MDEQ Generic Residential and Commercial I Direct Contact Criteria (DCC) is to protect against adverse health effects due to long-term ingestion of and dermal exposure to contaminated soil. The generic DCC assume that a person is exposed to contaminated soil 350 days per year. The generic DCC may be adjusted to address the protection of persons who might come into occasional contact with contaminated floodplain soils, such as near Muskegon's Farmer's Market . The following discussion will demonstrate how the criteria were adjusted to account for a person coming into contact with contaminated soil at Farmer's Market each day the market is open to the public. To be protective, MDCH assumed that a person would be exposed from childhood through adulthood.

Arsenic is a known human carcinogen (EPA 1998). Benzo(a)pyrene is a probable human carcinogen (EPA 1994). The equation used to determine the Residential DCC of a known or probable carcinogen is below (MDEQ 2001):

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

TR is the target cancer risk, or the acceptable risk. An "acceptable" risk may range from 1 in 10,000 to 1 in 1,000,000, meaning that no more than one additional person in ten thousand (1E-4) or one million (1E-6) persons who are exposed to a specific carcinogen will die from cancer compared to a similar population not exposed to the carcinogen. The target risk in this exercise is set at 1 in 100,000 (**1E-5**).

AT is the averaging time factor, which, for carcinogens, is equivalent to the average human lifespan of 70 years, or **25,550 days**. When a chemical is found to be carcinogenic in laboratory animals, the research typically involves a high dose of the chemical given to the animal over a short period of time. Based on the assumption that a high dose of a carcinogen received over a short period of time is equivalent to a corresponding low dose spread over a lifetime, human exposures are calculated by prorating the total cumulative dose over an average person's lifetime.

CF is the conversion factor used so that the appropriate units appear in the product of the equation. This factor is equal to 1,000,000,000 micrograms per kilogram (**1E+9 µg/kg**).

SF is the oral cancer slope factor, which is an estimate of the increased cancer risk from a lifetime exposure to a chemical. It is a probability estimate that is used only for comparative purposes. It is not a predictive tool. The SF for arsenic is 1.5 per milligram per kilogram-day [**1.5 $(mg/kg\text{-}day)^{-1}$**] (EPA 1998). The SF for benzo(a)pyrene is 4.1 $(mg/kg\text{-}day)^{-1}$ (EPA 1994).

EF_i is the ingestion exposure frequency. It is assumed in this exercise that a child or adult would be exposed to the soil at Farmer's Market four days per week during the summer (13 weeks) and one day per week during the rest of the market's season (22 weeks), for a total of **74 days/year**.

IF is the age-adjusted soil ingestion factor. It assumes that a child through the age of six years eats 200 mg of soil per day, and that an adult will eat 100 mg of soil per day for 24 years. Each ingestion total (years X amount eaten/year) is divided by the respective default body weight and the resulting quotients are summed. In this exercise, the ATSDR default child body weight of 10 kg was used rather than the EPA default of 15 kg, to provide greater protection. Therefore, IF in this exercise equals **154 mg-year/kg-day**.

AE_i is the ingestion absorption efficiency (a science-based estimate of what percentage of a chemical is absorbed through the gastrointestinal tract) and is chemical-specific. The AE_i for arsenic and benzo(a)pyrene is **0.5** (50 percent) (MDEQ 2003).

EF_d is the dermal exposure frequency. Similar to EF_i above, it is assumed that a person would be exposed to the soils at Farmer's Market **105 days/year**.

DF is the age-adjusted soil dermal factor. It considers exposed skin surface area, a soil adherence factor (AF), number of events per day, and the exposure duration and divides the product of those factors by the body weight. Respective subfactors are determined for a child and an adult and then summed. The default AF for children is 0.2 milligrams per square centimeter (mg/cm^2), meaning 0.2 mg of soil would adhere to each square centimeter of exposed skin (MDEQ 2001). The default AF is applicable to the 95th percentile of children playing in dry soil (95 percent of children would have less soil adhering). Similar to the IF above, MDCH used the ATSDR default child body weight of 10 kg when calculating the DF. No adjustments were made for the adult subfactor. The DF in this exercise is equal to **459.6 mg-year/kg-day**.

AE_d is the dermal absorption efficiency (a science-based estimate of what percentage of a chemical is absorbed through the skin) and is chemical-specific. The value for arsenic is **0.03** (3 percent). The value for benzo(a)pyrene is 0.13 (13 percent).

The adjusted Residential DCC for arsenic is calculated as follows:

$$Adjusted\ Re\,sidentialDCC_{Arsenic} = \frac{1E-5 \times 25{,}550 \times 1E+9}{1.5[(74 \times 154 \times 0.5) + (74 \times 459.6 \times 0.03)]}$$

$$Adjusted\ Re\,sidentialDCC_{Arsenic} = 25{,}353\,\mu g/kg = 25 mg/kg$$

The units mg/kg are equivalent to parts per million (ppm).

The adjusted Residential DCC for benzo(a)pyrene is calculated as follows:

$$Adjusted\ Residential DCC_{Benzo(a)pyrene} = \frac{1E-5 \times 25{,}550 \times 1E+9}{4.1[(74 \times 154 \times 0.5) + (74 \times 459.6 \times 0.13)]}$$

$$Adjusted\ Residential DCC_{Benzo(a)pyrene} = 6{,}158\,\mu g / kg = 6\,mg / kg$$

Certification

This **Ryerson Creek Sediments** 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, CAT, SPAB, DHAC, ATSDR