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Technical Memorandum
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A Review of Human Health Risk Assessment: Nyanza Superfund Site Operable Unit IV Sudbury River Mercury Contamination

1. Introduction

At the request of the Metropolitan Area Planning Council and MetroWest Growth Management Committee (hereafter The Council and the Management Committee) Exponent staff is conducting a series of tasks related to the assessment of risk associated with the Sudbury River as a result of the Nyanza Superfund (CERCLA) site in Ashland, Massachusetts. The first task, presented here, is a critical review of the human health risk assessments (HHRA) for the Sudbury River that identifies any data gaps. This task will be followed by a public health assessment, which will draw on the results of this review and will seek to refine the HHRA and make recommendations to reduce risk. Other tasks that will be conducted as relevant documents become available include a review of the ecological risk assessment for the Sudbury River and a critical review of the U.S. Environmental Protection Agency (EPA) proposed clean-up plan. This memorandum presents the results of the first task, a critical review of the document entitled *Human Health Risk Assessment: Nyanza Superfund Site Operable Unit IV Sudbury River Mercury Contamination* prepared by Avatar Environmental for the EPA (hereafter referred to as Avatar 2006). This review is divided into the following tasks:

- **Task 1:** Review the risk estimates of the HHRA for accuracy and completeness. Review toxicity values to ensure they are consistent with the state of the art. Identify data gaps.
- **Task 2:** Review available information on demographics and examine suitability of fish consumption rates used in the HHRA.
- **Task 3:** Compare mercury concentrations in fish tissue from the Sudbury River to regional and national fish tissue concentrations.

- **Task 4:** Evaluate calculation of exposure point concentrations (EPCs) for individual species of fish.

- **Task 5:** Evaluate groupings of fish tissue concentration by reach of river relative to patterns of exposure for fish and consumers.

The goal of this review was to assist in interpreting the findings, in an effort to help the Council and Management Committee and the public understand potential risks associated with consumption of fish from the Sudbury River site. In addition, because some degree of the mercury present in fish is a result of global atmospheric mercury cycling, comments are provided regarding the risks associated with fish consumed from the Sudbury River versus fish from other locations regionally and nationally, as well as the health benefits of fish consumption.

The major findings of this review, presented in detail in the following sections, include:

- The HHRA for the Sudbury River provides a careful and thorough assessment of risks to consumers of fish from exposure to mercury. Because the HHRA includes numerous health protective assumptions, it is very unlikely to underestimate risks, but may overestimate risks from many site users.

- Exposure assumptions for subsistence and ethnic scenarios have considerable uncertainty for several reasons. For example, the existence of a population that uses self-caught fish as a primary protein in the diet is unsubstantiated. In addition, the HHRA uses estimated fish ingestion rates for subsistence fishers (e.g., 142.4 g fish consumed per day, or 220 8-oz. meals per year, assuming 350 events per year) that are based on an upper estimate (e.g., the 99th percentile of the U.S. population) for consumption of fresh and estuarine fish and shellfish from large and rich aquatic resources, a rate that may overestimate consumption of freshwater fish from individual reaches of the Sudbury River.

Major gaps in data or presentation of risks, presented in detail in the following sections, include:

- The HHRA for the Sudbury River lacks an executive summary that discusses key issues, including the uncertainty related to the presence of subsistence fishers. In addition, the executive summary should more clearly summarize the extent to which fish tissue concentrations and associated risk are elevated in comparison to reference locations. For example, although maximum concentrations in fish tissue are clearly elevated in the Sudbury River in comparison to reference location fish, median concentrations, which are more representative of long term exposure, are only moderately (i.e., less than 4-fold) elevated in comparison with reference locations.

- The Sudbury River HHRA should clarify which species and sizes of fish are associated with increased risk in comparison to fish from reference sites. For example, because larger fish tend to have higher concentrations of mercury. The confounding influence of fish size on mercury concentrations should be accounted for in order for comparison to be made among species and locations.

2. Review of the HHRA

Task 1: Review the Risk Estimates of the Human Health Risk Assessment for Accuracy and Completeness and Identify Data Gaps

Review for Accuracy and Completeness

The subject report was reviewed for clarity, accuracy (i.e., spot checks of a subset of calculations, and cross checks of tables were conducted), and technical rigor of the risk assessment assumptions relative to EPA guidance, the scientific literature and professional opinion. The Avatar (2006) HHRA is careful and thorough. No errors were found in spot checks on calculations and on comparisons among tables. The Avatar (2006) risk assessment follows a prior assessment, which narrowed the focus of potential issues to fish consumption (i.e., surface water and sediment risks were found to not be of concern) and to mercury contamination. The prior assessment has not been reviewed here.

Identification of Data Gaps

The document would benefit from an executive summary, which would provide an overview for readers. Because the HHRA includes numerous health protective assumptions related to both exposure and toxicity, it is very unlikely to underestimate risks, but may overestimate risks for many or even most site users. In this regard, several points may benefit from further consideration in relaying this information to the public. Main issues identified in these comments include the following:

- Published site-specific consumption survey data are not available to conduct the risk assessment for the Sudbury River. Exposure assumptions applied for subsistence and ethnic scenarios have considerable uncertainties in applicability to this population, and may be best presented in an uncertainty assessment. The use of these exposure scenario assumptions resulted in hazard indices far above acceptable levels. However, as noted below, application of the subsistence-level fish consumption rates to the reference areas would also result in hazard indices greater than one. The HHRA would benefit from discussion of this issue earlier in the document.

- Maximum mercury concentrations in fish tissue are clearly elevated in the Sudbury River in comparison to reference location fish, but medians, which are more representative of long term exposure, are not significantly elevated in all reaches (Table 5-13 of Avatar 2006). In addition, observed increases in median concentrations in certain reaches are moderate (i.e., less than 4-fold) in comparison with reference locations (Table 5-14 of Avatar 2006). This should be made more clear earlier and throughout the document.

- Further analyses that clarify which species and sizes of fish are associated with increased risk in comparison to fish from reference sites, and the degree of those increases, would be helpful. The confounding influence of fish size on mercury concentrations must be recognized and accounted for. This information is needed for the public to make choices about using this resource relative to other freshwater resources in the region.

- Uncertainties related to the toxicity value used to analyze methylmercury (i.e., the EPA reference dose [RfD]) in risk assessment can be considered in evaluating site hazards.
- Benefits of fish consumption can also be considered in risk management and communication with the public.

These issues are discussed further in the following sections.

Task 2: Review Available Information on Demographics and Examine Suitability of Fish Consumption Rates Used in the HHRA

Selection of an appropriate fish consumption rate depends on understanding the potentially affected populations, the attractiveness and accessibility of the water resource relative to other fishing locations, and the productiveness of the resource. No site-specific consumption data were identified by EPA, nor were any identified in this review or in EPA guidance documents. It is understandable that the risk assessment has selected assumptions that will not underestimate risks in order to provide adequate protection of public health. However, the uncertainties, and in this case particularly the degree to which assumptions tend to overestimate risks, can be better characterized to assist members of the public in making choices for themselves and their families. Uncertainties in the degree to which selected consumption rates for recreational anglers and subsistence anglers represent potential current or future site users are discussed in this section.

Recreational Anglers

The Ebert et al. (1993) Maine Angler Survey used in the Avatar (2006) HHRA is a well-designed study for use as the basis for recreational fish consumption rates. As indicated in Avatar (2006), because only 1 percent of Maine riverine environments were under advisories at the time of the Ebert study, anglers were likely not limiting their fish consumption in response to advisories at the time. However, some aspects of the application of these survey results may tend to overestimate exposure from a given reach of the Sudbury River. Specifically, Ebert et al. (1993) evaluated consumption from three types of resources: River and stream (flowing waters) of shallow to moderate depth; lake and pond (little or no flow); and all waters – water stretches that incorporate elements of both regimes. Application of the "All Waters" category from Ebert et al. (1993) to some of the relatively small reaches of the Sudbury River seems likely to overestimate exposure because the All Waters category refers to all of the resources used by the angler in fishing. Consistent with this, the All Waters category was also roughly equivalent with the sum of the other two categories. Specifically, the all waters consumption rate was 32 g/day, while rivers and streams (flowing) were 14 g/day and lakes and ponds (standing) were 18 g/day. An alternate approach suggested to address the reaches that incorporate both standing and flowing waters would be to apply the average of the two rates. If such an approach were applied it would reduce risk estimates approximately two-fold for reaches where the All Waters rate was applied.

Subsistence Anglers

The HHRA included a scenario that assumes that site users consume fish at a subsistence level on a reach-by-reach basis. Subsistence consumption is typically defined as use of a self-caught food resource as a primary protein source in the diet. Native Americans living in settings where they engage in traditional lifestyle activities (U.S. EPA 1997a) have been identified as consuming larger amounts of fish than the general population or than Native Americans who are no longer living within a traditional community. In addition, Asian Americans have also been identified as a group with a high level of fish consumption, but much of this consumption was of grocery store fish (U.S. EPA 1999). As noted on page 4-4, the HHRA does not identify a specific subsistence community, noting, "[s]uggestions that subsistence fishing may in fact occur on the river appear to be largely anecdotal." The uncertainty assessment indicates that such a community "is unsubstantiated" (p. 6-1). Nevertheless, the risk assessment consistently refers to "subsistence" site visitors within most of the document as though the population was an established fact, including the risk characterization where risk estimates for this population are calculated to be well above acceptable levels. In future tasks, Exponent will gather additional information to provide a qualitative assessment of the potential for such high level use of the site.

Given the high degree of uncertainty regarding whether such a population exists in this area, it would be more reasonable to include any analysis of this hypothetical scenario in the Uncertainty Assessment and to identify risk calculations related to the subsistence scenario as hypothetical. Moreover, to make these calculations more understandable for the public, it would be helpful to also provide the intake assumptions in terms of meals per year. For example, a 142.4 g/day intake rate would be equivalent to 220 8-oz meals per year.

Use of a 99th percentile consumption rate for subsistence evaluations appears to be above a reasonable maximum' exposure estimate—Even if a subsistence population is present, the application of a fish consumption rate of 142.4 g/day (220 8-oz meals per year) appears to be much higher than would seem to be representative of the reasonable maximum exposure (RME), both because of the percentile selected and the basis in the underlying data. The subsistence intake rate is based on the 99th percentile of the U.S. population and was derived from the Continuing Survey of Food Intakes by Individuals (CSFII) for the years 1994 to 1996. The application of a 99th percentile value is by definition an overestimate for 99 percent of the population.

The basis of the 142.4 g/day value is described in the U.S. EPA (2000) guidance document, which also uses this 142.4 g/day intake number for subsistence calculations and identifies it as being based on "uncooked weights of fresh and estuarine finfish and shellfish." Thus, because this rate includes consumption of estuarine fish and shellfish, the intake amount reflects intake from a broader array of resources than are present in the Sudbury River. Moreover, U.S. EPA (2002) includes CSFII data for 1994, 1996, and 1998 and indicates that intake rises sharply between the 90th and 99th percentile. The document reports intakes of 12 g/day (90th);

42 g/day (95th), and 123 g/day (99th), indicating that intake is highly variable at the upper end of the distribution. For this reason, risk assessments typically do not apply 99th percentile values. Data presented in U.S. EPA (2002) also indicate that inclusion of more recent data decreases the upper end consumption rate applied here from 142.4 to 123 g/day at the 99th percentile. The portion represented by shellfish is indicated in U.S. EPA (2002) Table 1 of Section 5.1.2, which provides a 99th percentile estimate of 95.28 g/day of finfish alone (uncooked) from freshwater and estuarine resources (as compared with 123 g/day for fish and shellfish). A 95th percentile estimate of 14.5 g/day for finfish alone is also provided. Evaluation of the underlying data that form the basis for the 142.4 g/day subsistence estimate suggests that this estimate is likely a substantial overestimate for Sudbury River anglers.

Consideration of a reach-by-reach consumption at a subsistence level seems unlikely— In settings where subsistence level consumption has been reported, seafood resources were gathered from large and rich aquatic resources. The application here of consumption at the 99th percentile in the United States population represents consumption of fish from every kind of resource including freshwater and estuarine finfish and shellfish. As such, it would not be expected to be representative of the amount of long-term intake that could be gathered from a more restricted freshwater resource such as the Sudbury River.

Area demographics do not support a subsistence exposure scenario—The identification of a subsistence consumption scenario for the Sudbury River is not consistent with the available information about the area population. For example, as described above subsistence consumption has clearly been identified in studies of Native American communities living together in a traditional lifestyle. Census data for Middlesex County, where the Nyanza site is located, indicate that 0.2 percent of the population identified themselves as Native American or Native Alaskan in the 2006 U.S. Census.[1] Middlesex County included 8.4 percent people who identified themselves as of Asian descent.

High fish consumption has also been reported in studies of Americans of Asian or Pacific Island descent. For example, a human health risk assessment for the Lower Duwamish River, which is

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[1] http://quickfacts.census.gov/qfd/states/25/25017.html

a freshwater and estuarine environment in Seattle, Washington, included risk estimates for seafood consumption by Asian and Pacific Islanders (API). Intake for an API population was derived assuming a total intake of 51.4 g/day, consisting of 7.1 g/day of fish and 44.4 g/day of shellfish present in that resource (U.S. EPA 1999; Kissinger 2005, as cited in Windward 2007). Intake estimates were derived to be representative of the demographics of that community and thus may not be entirely representative here. However, intake was not highly variable between Asian American subgroups, and thus these analyses of the API population can be used to consider potential intake for Asian subpopulations on the Sudbury River. Given the freshwater nature of the Sudbury River, shellfish are not expected to be a consumed resource. Evaluating the *fish* consumption rates from the U.S. EPA (1999) study of API populations suggests that use of the rates from Ebert et al. (1993) to represent recreational fishers on the Sudbury River would also be protective of Asian American populations based on fish consumption.

Ethnic Angler Scenario

An ethnic angler scenario was evaluated using the same assumed 142.4 g/day consumption rate described above for the subsistence scenario. This scenario was considered in order to evaluate risks associated with consumption of whole-body fish. The comments made above related to the subsistence scenario are also applicable to this assumed scenario and, like the subsistence scenario, given the considerable uncertainties related to this exposure scenario, it would be best included within the uncertainty assessment. Risk estimates associated with consumption of reference area fish should be shown in parallel with estimates for this and the subsistence scenario within any public communication. In discussing this scenario in Section 7.1.3, the authors note the considerable uncertainties associated with this assumed estimate:

> As with the subsistence angling population, information supporting the presence of individuals who prepare and consume the entire (i.e., whole body) fish caught from the Sudbury River as their sole source of dietary protein is largely anecdotal. Nevertheless, should these individuals exist, the following summarizes their potential health risk from mercury exposure.

Task 3: Compare Mercury Concentrations in Fish of the Sudbury River to Regional and National Concentrations

In order to compare concentrations of mercury among fish from various reaches of the Sudbury River and interpret differences in relation to regional and national concentrations, it is important to understand the recognized confounding influence of fish size on mercury concentrations (Hutcheson et al. 2008). For example, Figure 1 shows the relationship between mercury concentrations and fish length for largemouth bass from the Sudbury River; larger fish tend to have higher concentrations of mercury. In this case, trends in the length of largemouth bass (e.g., larger in Reaches 2 and 3 than in reaches 1 and 4) tend to follow trends in mercury concentrations (Figure 2). Comparison of concentrations among reaches and to reference sites should be made on a length-normalized basis, so that differences in concentrations that are potentially attributable to local sources can be distinguished from differences that result from the size of the fish.

Some general comparisons can be made using existing data, however. The discussion in Section 5 of the HHRA describes comparisons with data from the three reference areas (Reach 1, Charles River, and Sudbury Reservoir). These comparisons indicate that concentrations are only moderately increased over the reference concentrations particularly in considering median (rather than maximum) concentrations. Table 5-14 of the HHRA provides statistical comparisons of the three species considered relative to their respective reference concentrations, but focuses primarily on difference in variability between the data sets. Downgradient data sets did have higher maximum values, while medians were more similar to reference. For risk assessment, however, estimates of the central tendency value (mean, median, or upper percentile on the mean) are the most representative of long term exposure, and variability is less important for evaluating risk. Table 5-15 of Avatar (2006) shows the ratios of hazard quotients from the site versus the respective reference location, and indicates that many of these ratios would round to one with the highest ratio being 4.5. The risk assessment would be made clearer by providing this comparison earlier in the document and in an executive summary. The use of subsistence level consumption rates in risk estimates results in high hazard indices for most areas, but readers and site users would benefit from understanding that risks are directly proportional to fish consumed and that site concentrations (and any risks) range from consistent with reference locations to up to 4.5 times background.

Readers should also be made aware that Massachusetts has a statewide advisory that warns sensitive human populations (e.g., pregnant women, women of childbearing age who may become pregnant, nursing mothers, and children under 12 years of age) to avoid consuming any native freshwater fish caught in the state (except stocked and farm-raised fish) because of unsafe levels of mercury (MDPH 2001). Note, however, that the statewide freshwater fish advisory does not apply to fish stocked in freshwater bodies by the Massachusetts Division of Fisheries and Wildlife, and does not apply to farm-raised freshwater fish sold commercially. In addition, approximately 52 percent of the rivers and lakes in Massachusetts sampled since 1983 are also subject to fish consumption advisories for the rest of the population as a result of mercury contamination (MDPH 2007). Many of these Massachusetts water bodies do not have local water discharge sources of mercury but are instead likely to be primarily impacted by atmospheric mercury deposition (Hutcheson et al. 2008).

Concentrations of mercury in the three large fish species sampled (bullhead, largemouth bass, and yellow perch) can be compared to fish tissue concentrations reported by the Massachusetts Department of Environmental Protection (MDEP 2006), by EPA nationally, and in the scientific literature. River-wide average mercury concentrations in fillets of Sudbury River fish, ranging from 270 to 730 ng/g (Avatar 2006, Table 2-2), are within the range of average mercury concentrations in fillet indentified in seventeen lakes analyzed by MDEP (2006), which ranged from121 to 986 ng/g [2]. The lakes studied by MDEP may have inputs from aerial deposition or from other sources, however, and do not necessarily represent background concentrations. Nonetheless, average concentrations for certain species in individual reaches of the Sudbury River slightly exceed the range reported by MDEP. For example, concentration of total mercury in fillets of largemouth bass in Reach 9 (1,070 ng/g) slightly exceeded the highest mean in the MDEP database of 986 ng/g. Sudbury River data are also within the wide range of concentrations identified in the EPA National Lake Fish Tissue data. Concentrations ranged from 23 to 6,605 ng/g in individual fillet samples from 486 sites nationally, which also may

[2] Because concentrations are declining, more recent data are more relevant for this comparison.

reflect input from known sources of mercury (U.S. EPA 2008). Thus, in addition to the reference concentration comparisons made in the report, these more general and wider area comparisons also suggest that Sudbury River fish concentrations are within the range observed in other state and national resources.

Task 4: Evaluate Calculation of Exposure Point Concentrations for Individual Species of Fish

Tables 4-2 through 4-25 in the HHRA (Avatar 2006) indicate that maximum tissue concentrations (rather than median or average concentrations) were used to develop the EPCs for many species of fish in individual reaches of the river. This was particularly the case for methylmercury, but maximum values for total mercury were also used for some species (e.g., bullhead in Reaches 1 and 2 and largemouth bass in Reach 1). It is not clear whether the use of these maximum values for certain species had a substantial influence on EPCs that were calculated from data on several species. It would be helpful to understand the impact of using maximum values, rather than estimates of the average value (e.g., median or upper 95th confidence limit on the mean value), on the risk estimates.

Task 5: Evaluate Groupings of Fish Tissue Concentration by Reach of River Relative to Patterns of Exposure of Fish and Consumers

The HHRA examines potential human health risks based on consumption of fish collected from individual reaches of the Sudbury River or the reference areas. For some reaches, the grouping of the collected fish data is presumably based on the assumption that the movement of fish within that reach is limited by the presence of dams. In order to identify dams on the Sudbury River that may serve as barriers to fish movement, we reviewed aerial photographs and contacted various agencies, such as the U.S. Geological Survey. Reaches 4, 5, and 6 are bounded by dams on both ends, and the uppermost, Reach 1, is bounded by the Pleasant Street Impoundment on its downstream end (Figure 3). The grouping of data into other reaches is not apparently based on fish movement. For example, because there are no dams or other apparent barriers to fish movement in Reaches 7, 8, 9, and 10, these groupings may have been made on the basis of assumed exposure to people. For example, Reach 8 includes the Great Meadow National Wildlife Refuge, a site that risk managers might want to consider separately. However, the HHRA does not provide any description of the rationale for the designation of any of the reaches. Reach 2, which is impacted directly by discharges from the site, is bounded upstream by the Pleasant Street Impoundment and in the middle of the reach by the Mill Pond Dam, but is not apparently bounded on its downstream reach. Therefore, fish that are downstream of the Mill Pond dam can also move into Reach 3. The distinction between Reaches 2 and 3 seems somewhat arbitrary and should be discussed in the HHRA. To understand the potential for anglers to access the various reaches of the Sudbury River, we also reviewed aerial photographs and talked with local agencies and individuals regarding access to the river. Table 1 lists potential access points, and indicates that all reaches have access points for anglers.

Although data for various species of fish are available, a species-weighted concentration is used to calculate doses and risks for each reach. The approach assumes that anglers eat an equal portion of each species collected from each reach. For example, in most reaches data for three species (largemouth bass, brown bullhead, and yellow perch) are used to calculate a reach-specific EPC as follows:

$$\text{EPC for use in dose and risk calculations} = \frac{EPC_{lmb} + EPC_{bb} + EPC_{yp}}{3}$$

The HHRA states that this approach was selected because the study on which the ingestion rate of recreational anglers was based (Ebert et al. 1993) used a similar approach. In the absence of information as to the species that people catch and consume, the uncertainty related to the use of these aggregate EPCs is difficult to quantify. The uncertainty section of the HHRA does, however, calculate the ratio of the aggregate EPC to the EPC for individual species (Avatar 2006, Table 6-1). For most reaches, the EPC for the largemouth bass is larger than the aggregate EPC, indicating that exposure and risk to people that consume only largemouth bass could be slightly underestimated (e.g., up to 2.45 times) by using the aggregate EPC. In most other cases, the EPC for individual species is smaller than the aggregate EPC, indicating that the HHRA could slightly overestimate risks to people that consume only those species.

A clearer presentation in the HHRA of the transport and fate of mercury in this waterway would be useful. Also, to supplement the Figures 2-1 and 2-2 provided in the HHRA, where all species are grouped, additional figures should be provided in these comments to show concentrations by species by reach. Finally, as discussed above, the risk assessment would be made clearer by providing length-corrected comparisons for species between reaches earlier in the document to help the reader better understand any site-related influence.

Page 1-2 of the HHRA states that for those reaches previously assessed, trends in fish tissue concentrations between 1993/1994 and 2003 would be examined. In addition, section 2.2.3 of the HHRA states that comparisons were made to identify changes in the levels of mercury in the edible fish tissue collected in 1993/1994 and again in 2003. These comparisons may have been made in a previous document, but they were not evident in the HHRA. A discussion of the trends in fish tissue concentrations should be included in the HHRA, as it would be useful to the public.

3. Additional Considerations

Uncertainties Related to the RfD for Methylmercury

Both EPA and ATSDR derived toxicity values to be protective of adverse noncancer effects of methylmercury and both agencies derived these values following consideration of all relevant data. However, although both the EPA RfD of 0.0001 mg/kg-day and the ATSDR minimal risk level (MRL) of 0.0003 mg/kg-day are intended to be protective of long term exposure, the MRL is 3-fold less conservative than the RfD. Two key studies were considered in detail by regulators in both analyses: a study conducted in the Seychelles Islands on a homogeneous population with high fish consumption; and a study conducted in the Faroe Islands, in which much of the mercury exposure resulted from intermittent consumption of pilot whale meat containing inorganic and methyl mercury as well as PCBs in addition to fish consumption. Both analyses followed children from birth, recording maternal mercury concentrations (maternal hair in Seychelles and placental cord blood in Faroe Islands) and examining neurological endpoints in children, seeking to identify any trends between mercury concentrations and neurological deficits. No such deficits were found in the Seychelles population, while the investigation conducted in the Faroe Islands population identified deficits in neurobehavioral endpoints in testing conducted at 7 years of age (ATSDR 1999).

One of the main reasons for the differences in toxicity values derived by the two groups was that ATSDR placed more reliance on the Seychelles data set as a more appropriate basis for derivation of a threshold for long-term effects of methylmercury. EPA placed increased reliance on investigations conducted in the Faroe Islands. The ATSDR profile on mercury notes numerous limitations of the Faroe Islands study including the following: concurrent exposure to PCBs that the Faroe Islands authors estimated were above the FDA tolerable daily intake for PCBs; intermittent and high exposure to mercury from consumption of pilot whale meat; neurobehavioral testing was not conducted until age 7 without evolution of intervening exposure to mercury during childhood; and finally, the lack of information in the cohort about maternal nutrition and smoking habits (ATSDR 1999).

ATSDR considered these issues and ultimately selected the study from the Seychelles Islands as the basis for the MRL. In that derivation, the mean total mercury concentration in maternal hair taken at parturition (15.3 ppm) was used to derive a daily no-observed-adverse-effect level (NOAEL) of 0.0013 mg/kg-day. An uncertainty factor of 4.5 was then applied to account for the following: 1) variability in hair-to-blood ratios among women and fetuses in the U.S. population (factor of 1.5), 2)the remainder of any inter-individual variability (factor of 1.5), and 3) differences in the tests employed in the Seychelles Islands and those in the Faroe Islands (factor of 1.5) (ATSDR 1999). The resulting MRL of 0.003 mg/kg-day is 3-fold greater than EPA's RfD, and is similar to the World Health Organization (WHO) permissible tolerable level for adults of 0.00048 mg/kg-day (WHO 1990).

In contrast, the EPA RfD for methylmercury was based on a benchmark dose calculated from the Faroe Island data indicating adverse effects in 7-year-olds at maternal daily intakes estimated at 0.857–1.472 μg/kg-day. The RfD of 0.0001 mg/kg-day was calculated through adjusting this dose by an uncertainty factor of 10 to account for pharmacokinetic variability and uncertainty in estimating an ingested mercury dose from cord-blood mercury concentration:

(factor of 3); and pharmacodynamic variability and uncertainty: (factor of 3). Because these are multipled to together the overall factor is 10 (9) (U.S. EPA 2001).

Using the MRL derived by ATSDR from the more representative data set in place of EPA's current RfD in the risk characterization of methylmercury would result in a three-fold reduction in hazard quotients. Uncertainties related to the toxicity value for mercury used in the approach can be considered in risk management and risk communication.

Benefits of Fish Consumption

Numerous studies have evaluated the benefits of fish consumption, particularly in the area of cardiac health. While analyses of health benefits are not a part of the risk assessment process, it may be appropriate to consider these benefits to provide perspective in making risk-management decisions and communicating risk to the public.

Fish has nutritional value, because it is high in protein and low in saturated fat. Fish also contains the essential mineral selenium, as well as vitamins D, B6, and B12 (U.S. EPA 2004a; Torpy 2006; Philibert et al. 2006).

The American Heart Association (AHA) has identified the following health benefits of fish consumption.

> We recommend eating fish (particularly fatty fish) at least two times a week. Fish is a good source of protein and doesn't have the high saturated fat that fatty meat products do. Fatty fish like mackerel, lake trout, herring, sardines, albacore tuna and salmon are high in two kinds of omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).
>
> Omega-3 fatty acids benefit the heart of healthy people, and those at high risk of—or who have—cardiovascular disease (AHA 2008).

The AHA goes on to state the following benefits of fish consumption in regards to cardiovascular disease (CVD):

> The ways that omega-3 fatty acids reduce CVD risk are still being studied. However, research has shown that they
>
> - decrease risk of arrhythmias, which can lead to sudden cardiac death
> - decrease triglyceride levels
> - decrease growth rate of atherosclerotic plaque
> - lower blood pressure (slightly) (AHA 2008).

In addition, the "Patient Page" of the *Journal of the American Medical Association* (JAMA) notes the same benefits and also goes on to state:

> Eating fish reduces the risk of death from heart disease, the leading cause of death in both men and women. Fish intake has also been linked to a lower risk of stroke, depression, and mental decline with age.[3]
>
> For pregnant women, mothers who are breastfeeding, and women of childbearing age, fish intake is important because it supplies DHA, a specific omega-3 fatty acid that is beneficial for the brain development of infants.

The Patient Page cites a recently published study in JAMA (Mozaffarian and Rimm 2006) that weighed the risks of consuming fish that may contain dioxins/furans, PCBs, and mercury, against the health benefits noted above. The authors concluded:

> For major health outcomes among adults, based on both the strength of the evidence and the potential magnitudes of effect, the benefits of fish intake exceed the potential risks. For women of childbearing age, benefits of modest fish intake, excepting a few selected species, also outweigh risk (Mozaffarian and Rimm 2006).

Studies Evaluating the Risks and Benefits of Fish Consumption Have Indicated a Balance with Risks

A recent study evaluated the hazards and benefits associated with consuming fish with "background" concentrations of mercury, estimated as ranging from 100 or 230 ng methylmercury/g (Gotchfeld and Burger 2005). Using the EPA RfD of 0.1 μg/kg-day for methylmercury, these authors estimated that the threshold for adverse effects from fish consumption was 27 g/day. Cardiac benefits from fish consumption were estimated to begin at

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[3] These benefits were also noted by Torpy (2006) and Philibert et al. (2006).

consumption rates of 7 to 32 g/day, with declines in benefits at consumption rates from 35 to 160 g/day, depending on the study and the cardiac endpoint examined. This study can be used to estimate a fish consumption rate for Sudbury River fish that corresponds to a threshold for beneficial and adverse effects. For example, highest exposure point concentration for the Sudbury River HHRA was estimated to be 936 ng/g (for Reach 3), which is about 4 times *higher* than the upper range of background concentrations examined by Gotchfeld and Burger (2005). To identify the threshold consumption rate for the Sudbury River for which benefits outweigh risks, the exposure rates cited by Gotchfeld and Burger (2005) can be divided by 4 to account for the higher concentration of mercury in Sudbury River fish. Thus, at the highest exposure point concentration (936 ng/g in Reach 3), a consumption rate of 7.0 g/day (which corresponds to 10.9 8-oz. meals per year, assuming 350 exposure events per year, as per the HHRA) represents the threshold at which the benefits of fish consumption could be expected to outweigh risks. Although the consumption rate assumed for the adult recreational angler in the HHRA in Reach 3 is higher than this threshold, reduction of consumption by 3 8-oz meals per year (i.e,. from 10.9 to 7.9 8-oz meals per year) would result in exposure that is within the range identified as having a potential benefit and below the adverse effect threshold. Thus, comparison to the estimates by Gotchfeld and Burger (2005) suggest that even where mercury is elevated in fish, if consumption if relatively moderate, cardiac benefits of fish consumption could outweigh potential incremental risk from exposure to mercury. Moreover, for any scenarios with hazard quotients below 1.0 (i.e., below a level of concern), which includes most of the central tendency estimates for recreational anglers, health benefits associated with fish consumption would be expected.

References

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