QUANTITATIVE RISK CHARACTERIZATION

Lake Meredith

Hutchinson, Moore, and Potter Counties, TX

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BACKGROUND AND STATEMENT OF ISSUES

The Texas Natural Resource Conservation Commission (TNRCC) requested that the Texas Department of Health (TDH) evaluate fish from Lake Meredith for potential public health hazards from consumption. TDH undertook that study, funded by the TNRCC through a grant to the Seafood Safety Division (SSD).

Lake Meredith, a 12,000 surface-acre reservoir with a storage capacity of 1,407,600 acre-feet, is located on the Canadian River 45 miles northeast of Amarillo (population 176,600 [2]) and 10 miles west of Borger (pop. 14,302), in Hutchinson County (population, 23,857) and extends into Moore (pop. 20,121) and Potter counties (pop. 113,546). Impounded by the Sanford Dam in 1965, Lake Meredith is operated by the Canadian River Municipal Water Authority, serving as a primary municipal water source for eleven West Texas cities, including Amarillo, Lubbock, and Plainview. Lake Meredith National Recreation Area, comprised of some 45,000 acres of canyon- and grassland, is the primary recreation site for the Texas Panhandle and surrounding area, having opportunities for boating, fishing, hunting, camping, picnicking, off-road vehicle use, and nature study. Annually, some 1½ million people visit this recreation area, many of them fishing for walleye, largemouth bass, smallmouth bass, crappie, white bass, bream, and catfish. Lake Meredith is the number-one fishing site for walleye in Texas and serves as a source of walleye used to stock other Texas lakes [3]. Several resort communities, including Sanford, Lake Meredith Estates, and Bugbee Heights, lie just outside park boundaries [3].

DISCUSSION

Collection and Analysis of Seafood Samples

To evaluate potential health risks to recreational and subsistence fishers who consume environmentally contaminated seafood, the Texas Department of Health (TDH) collects and analyzes samples of edible seafood tissues from the state's public waters that represent the species, trophic levels and legal-sized specimens available for consumption. When practical, TDH collects samples from several sites within a water body to characterize the geographical distribution of contaminants. The TDH laboratory utilizes established methodology to analyze edible fillets (skin off) of fish and edible meats of shellfish for seven metals – arsenic, cadmium, copper, lead, mercury[1], selenium, and zinc – and for a large number of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs: Aroclors 1016, 1221, 1224, 1232, 1248, 1254, and 1260).

Description of Lake Meredith Sample Set

In autumn, 2000, the TDH Seafood Safety Division (SSD) collected twenty-five fish from five subsites within Lake Meredith. Samples consisted of one black crappie, one blue catfish, seven channel catfish, four flathead catfish, four largemouth bass, four walleye, one warmouth, one white bass and two white crappie. All samples complied with applicable regulations for

[1]Nearly 100% of the mercury in upper trophic-level fish is methylmercury [2]. Total mercury concentration is a conservative surrogate for methylmercury concentration in fish and shellfish. Thus, TDH analyzes fish and shellfish tissues for total mercury, which includes that found as methylmercury and as ionic mercury. In this risk characterization, "mercury" and "methylmercury" are used interchangeably.

possession [4]. The TDH laboratory analyzed five samples (one walleye, two flathead catfish, a largemouth bass and a white bass) for metals, VOCs, SVOCs, PCBs and various pesticides. The remaining twenty fish were analyzed only for mercury.

Results

Chemical Analyses

One flathead catfish analyzed for organics contained minimal quantities of chlordane and p,p'-DDE (data not shown). The walleye and a flathead catfish contained acetone, a common laboratory contaminant or a possible result of post-collection sample degradation (data not shown). Three fish analyzed for the seven metals contained some cadmium; one contained copper; another contained lead, while all five contained selenium and zinc. Detectable levels of mercury were present in twenty-four of the twenty-five samples from Lake Meredith.

Statistical Analyses

All statistical procedures were performed on IBM-compatible microcomputers using SPSS software [5]. Summary statistics, including average concentrations, standard deviations, medians, ranges, and minimum and maximum values were generated by the SPSS OLAP Cube procedure. SPSS GLM was used to test hypotheses. Hazard analyses and allowable meals were calculated, when appropriate, using a spreadsheet formatted in Microsoft Excel [6].

Derivation of Health-Based Assessment Comparison Values (HACs)

Generally, people who regularly eat contaminated seafood are exposed to low concentrations of contaminants over an extended time. This pattern of exposure seldom results in acute toxicity but may increase the risk of subtle, delayed or chronic adverse health effects. Presuming that people eat a variety of fish, TDH routinely evaluates average contaminant concentrations across species and locations within a specific water body since this approach best reflects the likely exposure pattern of consumers over time. However, the agency also may examine the risks associated with ingestion of individual species of fish or shellfish from individual collection sites.

TDH evaluates chemical contaminants in fish by comparing average contaminant concentrations with health-based assessment comparison (HAC) values (in mg contaminant per kg edible tissue or mg/kg) for non-cancer and cancer endpoints. To calculate the associated HAC values for both carcinogenic and systemic effects, TDH assumes that a standard adult weighs 70 kilograms and that adults consume 30 grams of fish per day (about one eight-ounce meal per week). TDH uses the U.S. Environmental Protection Agency's (USEPA) oral reference doses (RfDs) or the Agency for Toxic Substances and Disease Registry's (ATSDR) chronic oral minimal risk levels (MRLs) to derive HAC values for evaluating systemic (noncancerous) adverse health effects (HAC_{nonca}). RfDs are estimates of long-term daily exposures that are not likely to cause adverse noncancerous (systemic) health effects even if exposure occurs over a lifetime [7]. Since MRLs and RfDs are similar concepts, the numbers from both agencies may be identical. However, in some instances, the RfD may differ from the MRL because scientific judgment or interpretation can vary between regulatory agencies. The cancer risk comparison values (HAC_{ca}) that TDH uses to assess carcinogenic potential from consumption of seafood containing carcinogenic chemicals are based on the USEPA's chemical-specific cancer slope factors (SFs), an acceptable lifetime risk level (ARL) of 1 excess cancer in 10,000 (1×10^{-4}) people exposed and an exposure period of 30 years.

Most constants employed to calculate HAC values contain built-in margins of safety (uncertainty factors). Uncertainty factors are chosen to minimize the potential for systemic adverse health effects in those people – including sensitive subpopulations such as women of childbearing age, pregnant or lactating women, infants, children, the elderly, people who have chronic illnesses, or those who consume exceptionally large quantities of fish or shellfish – who eat environmentally contaminated seafood. Therefore, adverse health effects are very unlikely to occur, even at concentrations approaching the HAC values. Moreover, health-based assessment comparison values do not represent a sharp dividing line between safe and unsafe exposures. The strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used by risk managers to assure protection of public health. TDH finds it unacceptable when consumption of four or fewer meals per month would result in exposures that exceed a HAC value or other measure of risk. People who wish to minimize exposure to environmental contaminants in seafood are advised to eat a variety of fish and shellfish and to limit consumption of those species that are most likely to contain environmental toxicants.

Addressing the Potential for Cumulative Effects

When multiple chemicals that affect the same organ or that have the same mechanism of action exist together in one or more samples from a water body, the standard assumption is that potential adverse health effects are cumulative (additive) [8]. Therefore, TDH conservatively assumes that each time people eat seafood from an affected water body, they will be exposed to all of the chemicals and, further, that any potential adverse systemic or carcinogenic effects from any of the contaminants will be cumulative (i.e., additive).

Cumulative Systemic (Noncancerous) Effects

To evaluate the importance of possible cumulative systemic (noncancerous) health effects from consumption of contaminants with similar toxicity profiles, TDH calculates a hazard index (HI) by summing the hazard quotients (HQ) previously calculated for each contaminant. The hazard quotient (HQ) is the ratio of the estimated exposure dose of a contaminant to its RfD or MRL. A HI of less than 1.0 may suggest that no significant hazard is present for the observed combination of contaminants at the observed concentrations. While a HI that exceeds 1.0 may indicate some level of hazard, it does not imply that exposure to the contaminants at observed concentrations will result in adverse health effects. Nonetheless, finding an HI that exceeds 1.0 may prompt the agency to consider some public health intervention strategy.

Cumulative Carcinogenic Effects

To estimate the potential additive effects of multiple carcinogens on excess lifetime cancer risk, TDH sums the risks calculated for each carcinogenic contaminant observed in a sample set. TDH recommends limiting consumption of seafood containing multiple carcinogenic chemicals to quantities that would result in an estimated combined theoretical excess lifetime cancer risk of not more than 1 extra cancer in 10,000 persons exposed.

Addressing Children's Unique Vulnerabilities

TDH recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and that any such vulnerabilities demand special attention. Windows of vulnerability (i.e., critical periods) exist during development. These critical periods are particularly evident during early gestation, but may also appear throughout pregnancy, infancy, childhood, and adolescence – indeed, at any time during development, when toxicants can permanently impair or alter the structure or function of vulnerable systems [9]. Unique childhood vulnerabilities may result from the fact that, at birth, most organs and body systems have not achieved structural or functional maturity, but continue to develop throughout childhood and adolescence. Because of these structural and functional differences, children may differ from adults in absorption, metabolism, storage, and excretion of toxicants, any one of which factors could increase the concentration of biologically effective toxicant at the target organ(s). Children's exposures to toxicants may be more extensive than adult's exposures because children consume more food and liquids in proportion to their body weight than do adults [9], a factor that also may increase the concentration of toxicant at the target. Children can ingest toxicants through breast milk – often unrecognized as an exposure pathway. They may also experience toxic effects at a lower exposure dose than adults due to differences in target organ sensitivity. Stated differently, children could respond more severely than would adults to an equivalent exposure dose [9]. Children may also be more prone to developing certain cancers from chemical exposures than are adults. If a chemical – or a class of chemicals – is shown to be more toxic to children than to adults, the RfD or MRL will be commensurately lower to reflect children's potentially greater susceptibility. Additionally, in accordance with ATSDR's *Child Health Initiative* [10] and USEPA's *National Agenda to Protect Children's Health from Environmental Threats* [9], TDH seeks to further protect children from the potential effects of toxicants in fish and shellfish by suggesting that this sensitive group consume smaller quantities of environmentally contaminated seafood than adults. Therefore, TDH routinely recommends that children who weigh 35 kg or less and/or who are eleven years of age or younger eat no more than four ounces of chemically contaminated fish or shellfish per meal. TDH also recommends that consumers spread these meals out over time. For instance, if the consumption advice recommends eating no more than two meals per month, children consuming seafood from the affected water body should eat no more than one meal every two weeks.

Risk Characterization

<u>Characterizing the Risk of Systemic (Noncancerous) Health Effects from Consumption of Contaminants in Lake Meredith Fish Samples</u>

Chlordane, a legacy chlorinated pesticide that adversely affects the livers of experimental animals [11], was present in only one (20%) of five fish tested for pesticides. The chlordane concentration in that fish (0.02 mg/kg), however, was far lower than HAC_{nonca} value for this toxicant. Thus, consumption of fish from Lake Meredith that contain chlordane should not increase the risk of systemic adverse health effects in those who consume those fish. This same sample - a flathead catfish - contained p, p'-DDE, a metabolite or breakdown product of another legacy pollutant, p, p'-DDT. The concentration of DDE in this fish was 0.008 mg/kg, many times lower than the HAC_{nonca} for DDT. Thus, the presence of small quantities of DDE in fish from Lake Meredith should not significantly increase risk of systemic adverse health effects in people who consume such fish from Lake Meredith. Although mercury occurs naturally in the earth's crust and is cycled through air, water, and soil, human activity – namely those of burning fossil fuels and other industrial activities – is a major source of the mercury deposited into the environment. Once in water or soil, bacteria transform inorganic forms of mercury into methylmercury, an organic form that is highly toxic to humans. Fish absorb and concentrate methylmercury from ambient waters into their tissues; as a result, most of the mercury in fish is likely to be methylmercury. Methylmercury is exceptionally toxic to the immature nervous system, producing adverse effects that vary from subtle to severe depending upon the circumstances of exposure [12]. Consumption of mercury-contaminated fish is typically the main source of exposure to this developmental toxicant [12]. Women who may become pregnant, lactating women, infants, and small children (up to and including 35 kilograms or up to and including 11 years of age) who regularly consume fish containing high concentrations of this toxicant, or those who eat such fish over a lengthy period, may be at increased risk of adverse health effects from exposure to methylmercury.

Twenty-four of the twenty-five samples from Lake Meredith contained mercury. The overall average mercury concentrations (averaged across species and subsites) did not exceed the HAC_{nonca} for methylmercury. However, walleye contained mercury in excess of the HAC_{nonca} for methylmercury (0.804 mg/kg; Table 1). The mercury concentration in the single white bass collected was 0.677 mg/kg, a borderline concentration. The hazard quotient for methylmercury in walleye was 1.15, while the hazard quotient for this contaminant in white bass was 0.97.

Characterizing the Risk of Cancer from Consumption of Contaminants in Lake Meredith Fish Samples

Chlordane, a chlorinated insecticide, is classified by the USEPA as a probable human carcinogen (Group B2), as is p,p'-DDE. This classification is based on reported increases in tumor incidence in experimental animals [11]. Chlordane and DDE concentrations in the flathead catfish from Lake Meredith were far below the HAC_{ca} for these contaminants, however. Thus, consumption of fish from Lake Meredith that contain chlordane or DDE should not increase the theoretical lifetime risk of cancer.

Few published reports of cancer in humans following exposure to methylmercury exist [11]. Although methylmercury has been associated with neoplastic changes in the kidneys of experimental animals, those changes generally occurred only at doses that caused significant systemic toxicity and were associated with alterations in structure or function that were classified as threshold effects [11]. Thus, although the USEPA has classified methylmercury as a possible human carcinogen (Group C) [11], it is likely that systemic non-cancerous effects would be seen at methylmercury exposures much lower than those required for tumor formation. Long-term administration of methylmercury to experimental animals produces overt symptoms of neurotoxicity at daily doses an order of magnitude lower than those required to induce tumors in mice. Thus, the USEPA has not derived a slope factor for methylmercury. It was, consequently, not possible to assess carcinogenic risk from consuming fish from Lake Meredith that contain methylmercury.

Characterizing the Likelihood of Cumulative Systemic Adverse Health Effects or Cancer from Consumption of fish from Lake Meredith

Two contaminants with similar toxicity profiles – chlordane and p,p'-DDE – were observed in fish from Lake Meredith. However, the hazard index for these two compounds was less than one, suggesting that consumption of fish containing chlordane and DDE at concentrations similar to those observed in the samples should not materially contribute to adverse systemic health effects or cancer in those who consume fish from Lake Meredith.

CONCLUSIONS AND PUBLIC HEALTH IMPLICATIONS

1. Average mercury concentration in walleye in the sample set from Lake Meredith exceeded the HAC_{nonca} value for methylmercury. Consumption of walleye therefore **poses a public health hazard.**

2. Mercury in the single white bass collected was 0.677 mg/kg, a number that approximates the HAC value for methylmercury (0.7 mg/kg). Although mercury in this white bass were near the HAC value, risk assessors are unable to draw scientifically valid conclusions about methyl mercury concentrations in white bass from Lake Meredith from one specimen. Consumption of white bass from Lake Meredith therefore **poses an indeterminate public health hazard.**

RECOMMENDATIONS

TDH risk managers have established certain criteria for issuing fish consumption advisories based on approaches suggested by the USEPA [13]. When a risk characterization confirms that consumption of four or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) would result in exposures to toxicants that exceed TDH health-based assessment guidelines, risk managers may wish to recommend that the Commissioner of Health issue consumption advice or ban possession of fish from the affected water body. Based on a quantitative assessment of the probability of increased risk of systemic adverse health effects from regular consumption of fish from Lake Meredith containing average concentrations of methylmercury, the Seafood Safety Division (SSD) and the Environmental Epidemiology and Toxicology Division (EE&TD) of the Texas Department of Health (TDH), recommend that:

1. TDH issues consumption advice for walleye from Lake Meredith recommending that people limit consumption of walleye to two meals per month.

2. TDH conducts additional studies of mercury in other fish species from Lake Meredith to determine whether consumption of other species from this reservoir poses a hazard to public health from mercury contamination.

PUBLIC HEALTH ACTION PLAN

TDH fish consumption advisories and bans are published in a booklet that is available to the public through the TDH Seafood Safety Division: (512-719-0215). This information is also posted on the Internet at URL: http://www.tdh.state.tx.us/bfds/ssd, which is updated regularly. Some risk characterizations for water bodies surveyed by the Texas Department of Health may also be available from the Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/HAC/PHA/region6.html). The Texas Department of Health provides all consumption advisory and ban information to the U.S. Environmental Protection Agency (URL: http://fish.rti.org), the Texas Natural Resource Conservation Commission (TNRCC; URL: http://www.tnrcc.state.tx.us) and the Texas Parks and Wildlife Department (TPWD; URL: http://www.tpwd.state.tx.us). Each year, the TPWD informs the fishing and hunting public of fishing bans in an official hunting and fishing regulations booklet [4] that is available at some state parks and at establishments that sell fishing licenses.

Readers may direct questions about the scientific information or recommendations in this risk characterization to the Seafood Safety Division (512-719-0215) or the Environmental Epidemiology and Toxicology Division (512-458-7269) at the Texas Department of Health. Toxicological information on a variety of environmental contaminants found in seafood and other environmental media may also be obtained from the Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology by telephoning that agency at the toll free number (800-447-1544) or from the ATSDR website (URL: http://www.atsdr.cdc.gov).

Table 1. Mercury (mg/kg) in Fish from Lake Meredith, 2000.

Species	# Detected/# Analyzed	Average Concentration (min to max)*	Health-based Assessment Comparison Value†	Basis for Comparison Value
Blue Catfish	1/1	0.390 (na‡)	0.7 mg/kg	ATSDR MRL: 0.0003 mg/kg/day
Channel Catfish	7/7	0.435 (0.163-0.620)		
Flathead Catfish	4/4	0.228 (0.136-0.389)		
Largemouth Bass	4/4	0.346 (0.214-0.598)		
Walleye	4/4	0.804 (0.437-1.14)		
White Bass	1/1	0.677 (na)		
Warmouth	1/1	0.192 (na)		
White Crappie	2/2	0.158 (0.123, 0.193)		
Black Crappie	0/1	Not Detected		
All Species	24/25	0.407 (nd-1.14)		

* *Minimum concentration to Maximum concentration (to calculate the range, subtract the minimum concentration from the maximum concentration).*
† *Derived from the MRL or RfD for noncarcinogens or the USEPA slope factor for carcinogens; assumes a body weight of 70 kg, and a consumption rate of 30 grams per day, and assumes a 30-year exposure period for carcinogens and an excess lifetime cancer risk of $1x10^{-4}$.*
‡ *nd-not detected at concentrations above the laboratory reporting limit.*

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