Characterization of Potential Adverse Health Effects Associated with Consuming Fish from

Clear Creek

Harris County, Texas

June 2009

Department of State Health Services
Division for Regulatory Services
Policy, Standards, and Quality Assurance Unit
Seafood and Aquatic Life Group
Austin, TX

INTRODUCTION

Blue crab and fish from Clear Creek, in Harris County, Texas examined in 1993 contained several environmental toxicants.[1] Taken from a creek section immediately downstream of the Brio Refinery National Priorities Superfund site, the samples contained volatile organic compounds (VOCs), chlordane, other chlorinated pesticides, mercury, and zinc. On November 18, 1993, based on data from that survey, the Texas Department of Health (TDH)[a] issued Advisory 7 (ADV-7).[2] ADV-7 recommended that no one consume fish or crabs taken from Clear Creek upstream and west of Texas Highway 3. Follow-up sampling in December 1993 revealed similar contaminants at similar levels. Cumulative cancer risk from carcinogenic contaminants in the December 1993 samples exceeded health department guidelines then in effect for protecting human health from the effects of chemical carcinogens. Soon thereafter, the Texas Natural Resource Conservation Commission (TNRCC)[b] listed Clear Creek on its 303(d) list. From 1993 until 2001, Clear Creek remained under ADV-7. In 2001, after repeat sampling showed only trace quantities of VOCs, the then TDH lifted its consumption advisory.[3] However, on July 8, 2008, the Texas Department of State Health Services (DSHS) issued Advisory 35 (ADV-35). ADV-35 recommended that persons should limit consumption of all catfish species and spotted seatrout from Galveston Bay including Chocolate Bay, East Bay, Trinity Bay, and West Bay and contiguous waters to no more than one eight-ounce meal per month. Women who are nursing, pregnant, or who may become pregnant and children under 12 should not consume catfish or spotted seatrout. The DSHS considers Clear Creek as contiguous waters of Galveston Bay. Thus, ADV-35 consumption recommendations apply to Clear Creek. The Texas Commission on Environmental Quality (TCEQ) requested the present survey of Clear Creek as a five-year follow-up study under the Total Maximum Daily Load (TMDL) program.

Description of Clear Creek

The Clear Creek watershed encompasses approximately 200 square miles and spans parts of Harris, Galveston, Brazoria and Fort Bend counties as well as sixteen cities.[4] The watershed includes two main stem streams: Clear Creek and Turkey Creek. Clear Creek, located in southern Harris County, Texas, flows west to east through the Clear Creek watershed to empty into Galveston Bay.[4]

Demographics of Harris County Surrounding the Area of Clear Creek

In 2007, the census bureau reported the population of Harris County to be 3,935,855 people.[5] Located on the upper Gulf Coast in Southeast Texas, Harris County comprises 1,778 square miles and primarily encompasses Houston, the county seat and Texas' largest city. Houston's estimated population in 2007 was 2,208,180. [6,7]

[a] Now the Department of State Health Services (DSHS)
[b] Now the Texas Commission on Environmental Quality (TCEQ)

Subsistence Fishing in Clear Creek

The United States Environmental Protection Agency (USEPA or EPA) suggests that, along with ethnic characteristics and cultural practices of an area's population, the poverty rate could contribute to the rate of subsistence fishing in an area.[8] The DSHS finds, in concert with the USEPA, that it is important to consider subsistence fishing to occur at any water body because subsistence fishers (as well as recreational anglers and certain tribal and ethnic groups) usually consume more locally caught fish than the general population. These groups sometimes harvest fish or shellfish from the same water body over many years to supplement caloric and protein intake. People who routinely eat chemically contaminated fish or shellfish from a water body – or those who eat large quantities of fish from the same waters – could unknowingly increase their risk of adverse health effects from that consumption. The EPA suggests that states assume that at least 10% of licensed fishers in any area are subsistence fishers. Subsistence fishing, while not explicitly documented by the DSHS, likely does occur. The DSHS assumes the rate of subsistence fishing to be similar to that estimated by the USEPA.[8]

The TMDL Program at the TCEQ and the Relationship between the TMDL Program and Consumption Advisories or Possession Bans Issued by the DSHS

The Texas Commission on Environmental Quality (TCEQ) enforces federal and state laws that promote judicious use of water bodies under state jurisdiction and protects state-controlled water bodies from pollution. Pursuant to the federal Clean Water Act, Section 303(d),[9] all states must establish a "total maximum daily load" (TMDL) for each pollutant contributing to the impairment of a water body for one or more designated uses. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and non-point sources. TMDLs incorporate margins of safety to ensure the usability of the water body for all designated purposes and to account for seasonal variations in water quality. States, territories, and tribes define the uses for a specific water body (e.g., drinking water, contact recreation, aquatic life support) along with the scientific criteria designated to support each specified use.[7]

Fish consumption is a recognized use for many waters. A water body is impaired if fish from that water body contain contaminants that make those fish unfit for human consumption or if consumption of those contaminants potentially could harm human health. Although a water body and its aquatic life may clear toxicants over time with removal of the source(s), it is often necessary to institute some type of remediation such as those devised by the TCEQ. Thus, whenever the DSHS issues a fish consumption advisory or prohibits possession of environmentally contaminated fish, the TCEQ automatically places the water body on its current draft 303(d) List.[7] TMDL staff members then prepare a TMDL for each contaminant present at concentrations that, if consumed, would be capable of negatively affecting human health. After approval of the TMDL, the group prepares an Implementation Plan for each contaminant. Upon "implementation," these plans facilitate rehabilitation of the water body. Successful remediation should result in return of the water body to conditions compatible with all stated uses, including consumption of fish from the water body. When the DSHS lifts a consumption advisory or possession ban, people may once again keep and consume fish from the water body. If fish in a water body are contaminated, one of the several items on an Implementation Plan for a water body on a state's 303(d) list consists of the periodic reassessment of contaminant levels in resident fish.

METHODS

Fish Sampling, Preparation, and Analysis

The DSHS Seafood and Aquatic Life Group (SALG) collects and analyzes edible fish from the state's public waters to evaluate potential risks to the health of people consuming contaminated fish or shellfish. Fish tissue sampling follows standard operating procedures from the DSHS *Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Control/Assurance Manual.*[10] The SALG bases its sampling and analysis protocols, in part, on procedures recommended by the USEPA in that agency's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1.*[11] Advice and direction are also received from the legislatively mandated *State of Texas Toxic Substances Coordinating Committee (TSCC) Fish Sampling Advisory Subcommittee (FSAS).*[12] Samples usually represent species, trophic levels, and legal-sized specimens available for consumption from a water body. When practical, the DSHS collects samples from two or more sites within a water body to better characterize geographical distributions of contaminants.

Fish Sampling Methods and Description of the Clear Creek 2007 Sample Set

In April 2007, SALG staff collected 25 fish samples from Clear Creek. Risk assessors used data from these fish to assess the potential for adverse human health outcomes from consuming fish from this creek.

Four sites were assigned to provide spatial coverage of the study area (see Figure 1 for approximate locations). Site 1 was located near Interstate Highway (IH) 45, Site 2 located at Challenger Park (Harris County), Site 3 near farm-to-market road (FM) 528, and Site 4 near FM 2351. Species collected represent distinct ecological groups (i.e. predators) that have some potential to bioaccumulate chemical contaminants, have a wide geographic distribution, are of local recreational fishing value, and/or that anglers and their families commonly consume. The 25 fish collected from Clear Creek represented all species targeted for collection from this water body. Table 1 lists species sampled, the number of each species collected, and the length and weight (in metric units) of each sample from each collection site. Species (number of samples) are as follows: channel catfish (7), blue catfish (6), smallmouth buffalo (4), common carp (4), longnose gar (2), flathead catfish (1), and alligator gar (1).

The SALG set gill nets in the late afternoon at each of the sample sites and fished those sites overnight. The gill nets were set in locations to maximize available cover and habitat. Staff retrieved captured fishes from the gill nets in the early morning hours, retaining only fish pre-selected as target samples. Staff immediately stored retrieved samples on wet ice in large coolers to ensure interim preservation, returning live fish culled from the catch to the water body.

SALG staff processed fish onsite at Clear Creek**.** Staff weighed each sample to the nearest gram (g) on an electronic scale and measured total length (tip of nose to tip of tail fin) to the nearest millimeter (mm). After weighing and measuring a fish, staff used a cutting board covered with aluminum foil and a fillet knife to prepare two skin-off fillets from each fish. The foil was changed and the knife cleaned with distilled water after each sample was processed. The team wrapped fillet(s) in two layers of fresh aluminum foil, placed in an unused, clean, pre-labeled plastic freezer bag, and stored on wet ice in an insulated chest until further processing. The SALG staff transported tissue samples on wet ice to their Austin, Texas, headquarters, where the samples were stored temporarily at -5° Fahrenheit (-20° Celsius) in a locked freezer. The freezer key is accessible only to authorized SALG staff members to ensure the chain of custody remains intact while samples are in the possession of agency staff. The week following the collection trip, the SALG shipped frozen fish tissue samples by commercial carrier to the Geochemical and Environmental Research Group (GERG) Laboratory, Texas A&M University, College Station, Texas, for contaminant analysis.

Analytical Laboratory Information

Upon arrival of the samples at the laboratory, GERG personnel notified the SALG of receipt of the 25 Clear Creek samples and recorded the condition of each sample along with its DSHS identification number.

Using established USEPA methods, the GERG laboratory analyzed fish fillets from Clear Creek for inorganic and organic contaminants commonly identified in polluted environmental media. Analyses included seven metals (arsenic, cadmium, copper, lead, total mercury, selenium, and zinc), 123 semivolatile organic compounds (SVOCs), 70 VOCs, 34 pesticides, and 209 polychlorinated biphenyl (PCB) congeners. The laboratory analyzed all 25 samples for metals, pesticides, PCBs, SVOCs, and VOCs,[13]

Explanatory Details of Specific Analyses

Arsenic

The GERG laboratory analyzed each of four fish for total (inorganic arsenic + organic arsenic = total arsenic) arsenic. Although the proportions of each form of arsenic may differ among fish species, under different water conditions, and, perhaps, with other variables, the literature suggests that well over 90% of arsenic in fish is likely organic arsenic – a form of arsenic that is virtually non-toxic to humans.[14] DSHS, taking a conservative approach, estimates 10% of the total arsenic in any fish is inorganic arsenic, deriving estimates of inorganic arsenic concentration in each fish by multiplying reported total arsenic concentration in the sample by a factor of 0.1.[14]

Mercury

Nearly all mercury in upper trophic level fish three years of age or older is methylmercury.[15] Thus, the total mercury concentration in a fish of legal size for possession in Texas serves well as a surrogate for methylmercury concentration. Because methylmercury analyses are difficult to perform accurately and are more expensive than total mercury analyses, the USEPA recommends that states determine total mercury concentration in a fish and that – to protect human health – states conservatively assume that all reported mercury in fish or shellfish is methylmercury. The GERG laboratory thus analyzed fish tissues for total mercury. In its risk characterizations, DSHS compares mercury concentrations in tissues to a comparison value derived from the Agency for Toxic Substances and Disease Registry's (ATSDR) minimal risk level (MRL) for methylmercury (in these risk characterizations, the DSHS may interchangeably utilize the terms "mercury," "methylmercury," or "organic mercury" to refer to methylmercury in fish).[16]

Polychlorinated Biphenyls (PCBs)

For PCBs, the USEPA suggests that each state measures congeners of PCBs in fish and shellfish rather than homologs or Aroclors® because the USEPA considers congener analysis the most sensitive technique for detecting PCBs in environmental media.[13] Although only about 130 PCB congeners were routinely present in PCB mixtures manufactured and commonly used in the U.S., the GERG laboratory analyzes and reports the presence and concentrations of all 209 possible PCB congeners. From the congener analyses, the laboratory also computes and reports concentrations of PCB homologs and of Aroclor® mixtures. Despite the USEPA's suggestion that the states utilize PCB congeners rather than Aroclors® or homologs for toxicity estimates, the toxicity literature does not reflect state-of-the-art laboratory science. To accommodate this inconsistency, the DSHS utilizes recommendations from the National Oceanic and Atmospheric Administration (NOAA),[17] from McFarland and Clarke,[18] and from the USEPA's guidance documents for assessing contaminants in fish and shellfish[11, 13] to address PCB congeners in fish and shellfish samples, selecting the 43 congeners encompassed by the McFarland and Clark and the NOAA articles. The referenced authors chose to use congeners that were relatively abundant in the environment, were likely to occur in aquatic life, and were most likely – as projected from structure –activity relationships – to show assessable toxicity.[17, 18] SALG risk assessors summed the 43 congeners to derive "total" PCB concentration in each sample.[17,18] SALG risk assessors then averaged the summed congeners within each group (e.g., fish species, sample site, or combination of species and site) to derive a mean PCB concentration for each group.

Using only a few PCB congeners to determine total PCB concentrations could underestimate PCB levels in fish tissue. Nonetheless, the method complies with expert recommendations on evaluation of PCBs in fish or shellfish. Therefore, SALG risk assessors compare average PCB concentrations of the 43 congeners with health assessment comparison (HAC) values derived from information on PCB mixtures held in the USEPA's Integrated Risk Information System (IRIS) database.[19] IRIS currently contains systemic toxicity information for five Aroclor® mixtures: Aroclors® 1016, 1242, 1248, 1254, and 1260. IRIS does not contain all information for all mixtures. For instance, only one other reference dose (RfD) occurs in IRIS – the one derived for Aroclor 1016, a commercial mixture produced in the latter years of commercial production of PCBs in the US. Aroclor 1016 was a fraction of Aroclor 1254 that was supposedly devoid of dibenzofurans, in contrast to Aroclor 1254.[20] Systemic toxicity estimates in the present document reflect comparisons derived from the USEPA's RfD for Aroclor 1254 because Aroclor 1254 contains many of the 43 congeners selected by McFarland and Clark and NOAA, and because, as of yet, IRIS does not contain information on the systemic toxicity of individual PCB congeners.

For assessment of cancer risk from exposure to PCBs, the SALG uses the USEPA's highest slope factor of 2.0 per (mg/kg/day) to calculate the probability of lifetime excess cancer risk from PCB ingestion. The SALG based its decision to use the most restrictive slope factor available for PCBs on factors such as food chain exposure; the presence of dioxin-like, tumor-promoting, or persistent congeners; and the likelihood of early-life exposure.[21]

Derivation and Application of Health-Based Assessment Comparison Values for Systemic Effects (HAC_{nonca}) of Consumed Chemical Contaminants

The effects of exposure to any hazardous substance depend, among other factors, on the dose, the route of exposure, the duration of exposure, the manner in which the exposure occurs, the genetic makeup, personal traits, habits of the exposed, or the presence of other chemicals.[22] People who regularly consume contaminated fish or shellfish conceivably suffer repeated low-dose exposures to contaminants in fish or shellfish over extended periods (episodic exposures to low doses). Such exposures are unlikely to result in acute toxicity but may increase risk of subtle, chronic, and/or delayed adverse health effects that may include cancer, benign tumors, birth defects, infertility, blood disorders, brain damage, peripheral nerve damage, lung disease, and kidney disease.[22]

If diverse species of fish or shellfish are available, the SALG presumes that people eat a variety of species from a water body. Further, SALG risk assessors assume that most fish species are mobile. SALG risk assessors may combine data from different fish species, blue crab, and/or sampling sites within a water body to evaluate mean contaminant concentrations of toxicants in all samples as a whole. This approach intuitively reflects consumers' likely exposure over time to contaminants in fish or shellfish from any water body but may not reflect the reality of exposure at a specific water body or a single point in time. The DSHS reserves the right to project risks associated with ingestion of individual species of fish or shellfish from separate collection sites within a water body or at higher than average concentrations (e.g. the upper 95 percent confidence limit on the mean). The SALG derives confidence intervals from Monte Carlo simulations using software developed by a DSHS medical epidemiologist.[23] The SALG evaluates contaminants in fish or shellfish by comparing the mean or the 95% upper confidence limit on the mean concentration of a contaminant to its HAC value (in mg/kg) for non-cancer or cancer endpoints.

In deriving HAC values for systemic (HAC_{nonca}) effects, the SALG assumes a standard adult weighs 70 kilograms and consumes 30 grams of fish or shellfish per day (about one 8-ounce meal per week) and uses the USEPA's RfD[24] or the ATSDR's chronic oral MRLs.[25] The USEPA defines an RfD as

> *An estimate of a daily oral exposure for a given duration to the human population (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health effects over a lifetime.*[26]

The USEPA also states that the RfD

> … *is derived from a BMDL* (benchmark dose lower confidence limit)*, a NOAEL* (no observed adverse effect level*), a LOAEL* (lowest observed adverse effect level)*, or another suitable point of departure, with uncertainty/variability factors applied to reflect limitations of the data used. [Durations include acute, short-term, subchronic, and chronic and are defined individually in this glossary]* and *RfDs are generally reserved for health effects thought to have a threshold or a low dose limit for producing effects.*[26]

The ATSDR uses a similar technique to derive its MRLs.[25] The DSHS divides the estimated daily dose derived from the measured concentration in fish tissue by the contaminant's RfD or MRL to derive a hazard quotient (HQ). The USEPA defines a HQ as

> *…the ratio of the estimated exposure dose of a contaminant (mg/kg/day) to the contaminant's RfD or MRL (mg/kg/day).*[27]

Note that, according to the USEPA, a linear increase in the HQ for a toxicant does not imply a linear increase in the likelihood or severity of systemic adverse effects. Thus, a HQ of 4.0 does not mean the concentration in the dose will be four times as toxic as that same substance would be if the HQ were equal to 1.0. A HQ of 4.0 also does not imply that adverse events will occur four times as often as if the HQ for the substance in question were 1.0. Rather, the USEPA suggests that a HQ or a hazard index (HI) – defined as the sum of HQs for contaminants to which an individual is exposed simultaneously) – that computes to less than 1.0 should be interpreted as "no cause for concern" whereas a HQ or HI greater than 1.0 "should indicate some cause for concern."

The SALG does not utilize HQs to determine the likelihood of occurrence of adverse systemic health effects. Instead, in a manner similar to the USEPA's decision process, the SALG may utilize computed HQs as a qualitative measurement. Qualitatively, HQs less than 1.0 are unlikely to be an issue while HQs greater than 1.0 might suggest a regulatory action to ensure protection of public health. Similarly, risk assessors at the DSHS may utilize a HQ to determine the need for further study of a water body's fauna. Notwithstanding the above discussion, the oral RfD derived by the USEPA represents chronic consumption. Thus, regularly eating fish containing a toxic chemical, the HQ of which is less than 1.0 is unlikely to cause adverse systemic health effects, whereas routine consumption of fish or shellfish in which the HQ exceeds 1.0 represents a qualitatively unacceptable increase in the likelihood of systemic adverse health outcomes.

Although the DSHS utilizes chemical specific RfDs when possible, if an RfD is not available for a contaminant, the USEPA advises risk assessors to consider evaluating the contaminant by comparing it to the published RfD (or the MRL) of a contaminant of similar molecular structure or one with a similar mode or mechanism of action. For instance, Aroclor® 1260 has no RfD, so the DSHS uses the reference dose for Aroclor 1254 to assess the likelihood of systemic (noncarcinogenic) effects of Aroclor 1260.[24]

In developing oral RfDs and MRLs, federal scientists review the extant literature to devise NOAELs, LOAELs, or benchmark doses (BMDs) from experimental studies. Uncertainty factors are then utilized to minimize potential systemic adverse health effects in people who are exposed through consumption of contaminated materials by accounting for certain conditions that may be undetermined by the experimental data. These include extrapolation from animals to humans (interspecies variability), intra-human variability, use of a subchronic study rather than a chronic study to determine the NOAEL, LOAEL, or BMD, and database insufficiencies.[24,26] Vulnerable groups such as women who are pregnant or lactating, women who may become pregnant, infants, children, people with chronic illnesses, those with compromised immune systems, the elderly, or those who consume exceptionally large servings are considered sensitive populations by risk assessors and USEPA and also receive special consideration in calculation of a RfD.[26, 28]

The primary method for assessing the toxicity of component-based mixtures of chemicals in environmental media is the HI. The USEPA recommends HI methodology for groups of toxicologically similar chemicals or chemicals that affect the same target organ. The HI for the toxic effects of a chemical mixture on a single target organ is actually a simulated HQ calculated as if the mixture were a single chemical. The default procedure for calculating the HI for the exposure mixture is to add the hazard quotients (the ratio of the external exposure dose to the RfD) for all the mixture's component chemicals that affect the same target organ, e.g., the liver. The toxicity of a particular mixture on the liver represented by the HI should approximate the toxicity that would have occurred were the observed effects caused by a higher dose of a single toxicant (additive effects). The components to be included in the HI calculation are any chemical components of the mixture that show the effect described by the HI, regardless of the critical effect from which the RfD came. Assessors should calculate a separate HI for each toxic effect.

Because the RfD is derived for the critical effect (the "toxic effect occurring at the lowest dose of a chemical"), a HI computed from HQs based on the RfDs for the separate chemicals may be overly conservative. That is, using RfDs to calculate HIs may exaggerate health risks from consumption of specific mixtures for which no experimentally derived information is available.

The USEPA states that

> *the HI is a quantitative decision aid that requires toxicity values as well as exposure estimates. When each organ-specific HI for a mixture is less than one and all relevant effects have been considered in the assessment, the exposure being assessed for potential systemic toxicity should be interpreted as unlikely to result in significant toxicity.*

And

> *When any effect-specific HI exceeds one, concern exists over potential toxicity. As more HI's for different effects exceed one, the potential for human toxicity also increases.*

Thus,

> *Concern should increase as the number of effect-specific HI's exceeding one increases. As a larger number of effect-specific HI's exceed one, concern over potential toxicity should also increase. As with HQs, this potential for risk is not*

the same as probabilistic risk; a doubling of the HI does not necessarily indicate a doubling of toxic risk.

Derivation and Application of Health-Based Assessment Comparison Values for Application to the Carcinogenic Effects (HAC_{ca}) of Consumed Chemical Contaminants

The DSHS calculates cancer-risk comparison values (HAC_{ca}) from the USEPA's chemical-specific cancer potency factors (CPFs), also known as cancer slope factors (CSFs), derived through mathematical modeling from carcinogenicity studies. For carcinogenic outcomes, the DSHS calculates a theoretical lifetime excess risk of cancer for specific exposure scenarios for carcinogens, using a standard 70-kg body weight and assuming an adult consumes 30 grams of edible tissue per day. The SALG risk assessors incorporate two additional factors into determinations of theoretical lifetime excess cancer risk: (1) an acceptable lifetime risk level (ARL) [26] of one excess cancer case in 10,000 persons whose average daily exposure is equivalent and (2) daily exposure for 30 years, a modification of the 70-year lifetime exposure assumed by the USEPA. Comparison values used to assess the probability of cancer do not contain "uncertainty" factors. However, conclusions drawn from probability determinations infer substantial safety margins for all people by virtue of the models utilized to derive the slope factors (cancer potency factors) used in calculating the HAC_{ca}.

Because the calculated comparison values (HAC values) are conservative, exceeding a HAC value does not necessarily mean adverse health effects will occur. The perceived strict demarcation between acceptable and unacceptable exposures or risks is primarily a *tool* used by risk managers along with other information to make decisions about the degree of risk incurred by those who consume contaminated fish or shellfish. Moreover, comparison values for adverse health effects do not represent sharp dividing lines (obvious demarcations) between safe and unsafe exposures. For example, the DSHS considers it unacceptable when consumption of four or fewer meals per month of contaminated fish or shellfish would result in exposure to contaminant(s) in excess of a HAC value or other measure of risk. The DSHS also advises people who wish to minimize exposure to contaminants in fish or shellfish to eat a variety of fish and/or shellfish and to limit consumption of those species most likely to contain toxic contaminants. The DSHS aims to protect vulnerable subpopulations with its consumption advice, assuming that advice protective of vulnerable subgroups will also protect the general population from potential adverse health effects associated with consumption of contaminated fish or shellfish.

Children's Health Considerations

The DSHS recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and suggests that exceptional susceptibilities demand special attention. [29, 30] Windows of special vulnerability (known as "critical developmental periods") exist during development. Critical periods occur particularly during early gestation (weeks 0 through 8) but can occur at any time during development (pregnancy, infancy, childhood, or adolescence) – times when toxicants can impair or alter the structure or function of susceptible systems.[31] Unique early sensitivities may exist after birth because organs and body systems are structurally or functionally immature at birth, continuing to develop throughout infancy, childhood, and adolescence. Developmental variables may influence the mechanisms or rates of absorption, metabolism, storage, or excretion of toxicants. Any of these factors could alter the concentration of biologically effective toxicant at the target organ(s) or could modulate target organ response to the toxicant. Children's exposures to toxicants may be more extensive than adults' exposures because children consume more food and liquids in proportion to their body weights than adults consume. Infants can ingest toxicants through breast milk, an exposure pathway that often goes unrecognized. Nonetheless, the advantages of breastfeeding outweigh the probability of significant exposure to infants through breast milk and women are encouraged to continue breastfeeding and to limit exposure of their infants by limiting intake of the contaminated foodstuff. Children may experience effects at a lower exposure dose than might adults because children's organs may be more sensitive to the effects of toxicants. Stated differently, children's systems could respond more extensively or with greater severity to a given dose than would an adult organ exposed to an equivalent dose of a toxicant. Children could be more prone to developing certain cancers from chemical exposures than are adults.[32] In any case, if a chemical or a class of chemicals is observed to be, or is thought to be, more toxic to fetuses, infants, or children, the constants (e.g., RfD, MRL, or CPF) are usually modified further to assure the immature systems' potentially greater susceptibilities are not perturbed.[24] Additionally, in accordance with the ATSDR's *Child Health Initiative*[33] and the USEPA's *National Agenda to Protect Children's Health from Environmental Threats,*[34] the DSHS further seeks to protect children from the possible negative effects of toxicants in fish by suggesting that this potentially sensitive subgroup consume smaller quantities of contaminated fish or shellfish than adults consume. Thus, DSHS recommends that children weighing 35 kg or less and/or who are 11 years of age or younger limit exposure to contaminants in fish or shellfish by eating no more than four ounces per meal of the contaminated species. The DSHS also recommends that consumers spread these meals over time. For instance, if the DSHS issues consumption advice that recommends consumption of no more than two meals per month of a contaminated species, those children should eat no more than 24 meals of the contaminated fish or shellfish per year and should not eat such fish or shellfish more than twice per month.

Data Analysis and Statistical Methods

The SALG risk assessors imported Excel© files into SPSS® statistical software, version 13.0 installed on IBM-compatible microcomputers (Dell, Inc) and used SPSS® to generate descriptive statistics (mean, standard deviation, median, minimum and maximum concentrations, and range) on measured compounds in each species from each sample site.[35] In computing descriptive statistics, SALG risk assessors utilized ½ the detection limit for analytes designated as not detected (ND) or estimated (J) values.[c] The SALG used the descriptive statistics from the above calculations to generate the present report. SALG protocols do not require hypothesis testing. Nevertheless, when data are of sufficient quantity and quality, and, should it be necessary, the SALG can utilize SPSS® software to determine significant differences among contaminant concentrations in species and/or at collection sites as needed. The SALG employed Microsoft Excel® spreadsheets to generate figures, to compute health-based assessment comparison values

[c] *"J-value" is standard laboratory nomenclature for an analyte concentration detected and reported below the laboratory's defined detection limit (DL) or reporting limit (RL). Such a reported concentration is an estimate quantitation of which may be suspect and may not be reproducible. The DSHS treats J-Values as "not detected" in its statistical analyses of a sample set.*

(HAC_{nonca} and HAC_{ca}) for contaminants, and to calculate HQs, HIs, cancer risk probabilities, and meal consumption limits for fish or shellfish from Clear Creek.[36] When lead concentrations in fish or shellfish are high, SALG risk assessors may utilize the USEPA's Interactive Environmental Uptake Bio-Kinetic (IEUBK) model to determine whether consumption of lead-contaminated fish could cause a child's blood lead (PbB) level to exceed the Centers for Disease Control and Prevention's (CDC) lead concentration of concern in children's blood (10 mcg/dL).[37, 38]

RESULTS

The GERG laboratory completed analyses and electronically transmitted the results of the Clear Creek samples collected in April 2007 to the SALG on December 31, 2008. The laboratory reported the analytical results for metals, pesticides, PCBs, SVOCs, and VOCs.

For reference, Table 1 contains the total number of samples collected. Tables 2a through 2d present the results of metals analyses. Tables 3a through 3e contain summary results of pesticides analyses, while tables 4a and 4b summarize the PCB analyses. This paper does not display SVOC and VOC data because these contaminants were not present at concentrations of interest in fish collected from Clear Creek during the described sampling trip. Unless otherwise stated, table summaries present the number of samples containing a specific toxicant/number tested, the mean concentration ± 1 standard deviation (68% of samples should fall within one standard deviation of the arithmetic mean in a sample from a normally-distributed population), and, in parentheses under the mean and standard deviation, the minimum and the maximum detected concentrations. Those who prefer to use the range may derive this statistic by subtracting the minimum concentration of a given toxicant from its maximum concentration. In the tables, results may be reported as ND, BDL (below detection limit), or as measured concentrations. According to the laboratory's quality control/quality assurance materials, results reported as "BDL" rely upon the laboratory's method detection limit (MDL) or its reporting limit (RL). The MDL is the minimum concentration of an analyte that be reported with 99% confidence that the analyte concentration is greater than zero, while the RL is the concentration of an analyte reliably achieved within specified limits of precision and accuracy during routine analyses. Contaminant concentrations reported below the RL are qualified as "J-values" in the data report.[39]

Inorganic Contaminants

Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc

All 25 fish tissue samples from Clear Creek contained some level of arsenic, copper, and zinc (Tables 2a- 2d). Most contained some combination of two or more metalloids comprised of cadmium, lead, or selenium.

Three of the metalloids analyzed are essential trace elements: copper, selenium, and zinc. All 25 fish tissue samples contained copper (Table 2b). The mean copper concentration in fish sampled from Clear Creek was 0.324±0.197 mg/kg. Common carp had the highest average concentration of copper (0.549±0.154 mg/kg). All samples also contained zinc (Table 2d). The mean zinc concentration in fish tissue samples from Clear Creek was 4.615±1.274 mg/kg. At 5.831±1.177 mg/kg, common carp also had the highest mean tissue zinc levels. All but one fish sample contained selenium. The average selenium concentration in fish from Clear Creek was 0.180 mg/kg with a standard deviation of ±0.089 mg/kg. Selenium in fish from Clear Creak ranged from ND to 0.424 mg/kg (Table 2d).

The SALG evaluated three toxic metalloids having no known human physiological function (lead, cadmium, and mercury) in the samples from Clear Creek. No fish from this stream contained cadmium at a concentration exceeding the laboratory's RL (Table 2b). Only one species (smallmouth buffalo) contained lead at concentrations greater than the RL. The average lead concentration in smallmouth buffalo was 0.108±0.106 mg/kg (Table 2c).

All species of fish collected in 2007 from Clear Creek contained mercury (Table 2c). Common carp contained the lowest average mercury concentration (0.037 ± 0.020 mg/kg). The single alligator gar – weighing 11.2 pounds and measuring 35.3 inches – contained the highest mercury concentration of all samples (0.261 mg/kg), a value greater than three standard deviations above the mean for combined species (0.089±0.065 mg/kg).Other species varied from 0.068 mg/kg to 0.175 mg/kg, averaging only 70% of mercury concentration in the alligator gar. The 2 longnose gar contained an average mercury concentration of 0.172 mg/kg.

Organic Contaminants

<u>Pesticides</u>

The GERG laboratory analyzed all fish for 34 pesticides. All 25 samples contained low concentrations of pentachlorobenzene and 24 of 25 samples contained low concentrations of hexachlorobenzene (Table 3a). Twenty of 25 samples contained low concentrations of heptachlor epoxide and methoxychlor (Tables 3b-3c). Three of 25 samples contained low levels of dieldrin and endrin (data not presented). Twenty-two of 25 samples contained small quantities of pentachloroanisole, while 10 of 25 samples contained low concentrations of mirex (data not presented). Twenty-three of 25 fish contained low concentrations of 2,4'- DDD (Table 3c) and 14 of 25 samples contained low levels of endosulfan I (data not presented). Tables 3a-3b and 3d-3e show that pentachlorobenzene, chlordane, 4, 4'-DDE, 4, 4'-DDD, and 2, 4'-DDT were present in all 25 fish sampled. Alligator gar contained the highest concentration (n=1) of chlordane, 4, 4'-DDE, and 4, 4'-DDD at 0.337 mg/kg, 0.299 mg/kg, and 0.030 mg/kg respectively (Tables 3a-3c). Smallmouth buffalo contained the highest concentration of pentachlorobenzene (n=4) at 0.003±0.0008 mg/kg, meanwhile, longnose gar contained the highest concentration of 2, 4'-DDT (n=2) at 0.006±0.007 mg/kg (Tables 3a; 3e). Flathead catfish contained the lowest concentrations of all detected contaminants (Tables 3a-3e). Alpha HCH, beta HCH, gamma HCH (lindane), delta HCH, heptachlor, aldrin, chlorpyrifos, 4,4'- DDT, alachlor, parathion ethyl, parathion methyl, and toxaphene were not present in any fish samples at a level greater than the reporting limit (data not presented).

Trace[d] quantities of 1,2,3,4-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, diazinon, dacthal, endosulfan II, endosulfan sulfate, and malathion were present in some fish samples (data not presented).

PCBs

The present study marks the first instance in which the SALG required analysis of fish tissue samples from Clear Creek for PCB congeners rather than Aroclors®. Thus, it is important that readers do not attempt to make direct comparisons between PCB concentrations in this report and Aroclor® concentrations from previous studies of Clear Creek.

Tables 4a and 4b contain summary results for total PCBs in the 25 fish collected in April 2007 from Clear Creek. All samples contained measurable concentrations of one or more PCB congeners (Table 4b). No sample contained all PCB congeners (data not shown). The SALG evaluated PCB concentrations in combined species at each sampling site. Under these conditions, fish from Site 1 (IH-45) contained the highest average PCB concentration (Table 4a-4b). Inspection of summary data (Table 4b) for PCBs within each species, regardless of collection site, showed the single alligator gar sample to contain the highest concentration of PCBs (0.418 mg/kg), followed by smallmouth buffalo (0.241±0.298 mg/kg) and then by longnose gar (0.211±0.274). The lone flathead catfish contained the lowest concentration of PCBs (0.016 mg/kg; Table 4b). The average PCB concentration in the 25 samples was 0.100±0.161 mg/kg (Table 4b).

SVOCs

The GERG laboratory analyzed the 25 Clear Creek samples for SVOCs. Reported in eight samples, bis (2-ethylhexyl) phthalate (BEHP or di-(2-ethylhexyl)phthalate or DEHP) was the only analyte measured at a concentration above the laboratory reporting limit (data not presented). Di-n-butyl phthalate (DBP) and 2-methylnaphthalene were also detected in some of the fish tissue samples – at estimated concentrations (J-values; data not presented). The laboratory detected no other SVOCs in fish from Clear Creek.

VOCs

The GERG laboratory reported the 25 fish tissue samples from Clear Creek to contain detectable concentrations of one or more VOCs (data not presented). For instance, 14 fish contained methylene chloride; nine (not necessarily the same samples as those containing other VOCs) contained carbon disulfide; and four contained toluene, and naphthalene. Chloromethane, vinyl chloride, bromomethane, 1,1-dichloroethene, acetone, chloroform, 1,2-dichloroethane, benzene, trichlorofluromethane, dichlorodifluoromethane, ethyl methacrylate, chlorobenzene, 1,4-dichlorobenzene, sec-butylbenzene, and n-butylbenzene were detected in some tissue samples at levels below the RL (estimated concentrations qualified as “J-values”; data not presented). The

---

[d] *Trace: in analytical chemistry, a trace is an extremely small amount of a chemical compound, one present in a sample at a concentration below a standard limit. Trace quantities may be designated with the “less than” (<) sign or may also be represented by the alpha character “J” – called a “J-value” defining the concentration of a substance as near zero or one that is detected at a low level but that is not guaranteed quantitatively replicable.*

procedural blanks contained no analytes at concentrations greater than three times the reporting limits (an indication that "unknowns" reported at concentrations less than ten times the level observed in the blank were not likely laboratory contaminants).

DISCUSSION

Risk Characterization

Because variability and uncertainty are inherent to quantitative assessment of risk, the calculated risks of adverse health outcomes from exposure to toxicants can be orders of magnitude above or below actual risks. Variability in calculated and in actual risk may depend upon factors such as the use of animal instead of human studies, use of subchronic rather than chronic studies, interspecies variability, intra-species variability, and database insufficiency. Since most factors used to calculate comparison values result from experimental studies conducted in the laboratory on nonhuman subjects, variability and uncertainty might arise from the study chosen as the "critical" one, the species/strain of animal used in the critical study, the target organ selected as the "critical organ," exposure periods, exposure route, doses, or uncontrolled variations in other conditions.[24] Despite such limitations, risk assessors must calculate parameters to represent potential toxicity to humans who consume contaminants in fish and other environmental media. The DSHS calculated risk parameters for systemic and cancerous endpoints in those who would consume fish from Clear Creek. Conclusions and recommendations predicated upon the stated goal of the DSHS to protect human health follow the discussion of the relevance of findings to risk. Meal consumption calculations are integral to the SALG's risk characterizations and are used by DSHS risk managers to determine whether consumption advice or regulatory actions might be necessary to protect human health from adverse effects of consuming toxicants in fish from Texas waters.

Characterization of Systemic (Noncancerous) Health Effects from Consumption of Fish from Clear Creek

The laboratory analyzed 25 fish collected in 2007 from Clear Creek for metalloid contaminants, pesticides, VOCs, SVOCs, and PCBs, examining several targeted species for targeted analytes. Inspection of raw data and summary statistics suggested these data were adequate to assess human health risks for individuals who consume fish from Clear Creek.

Inorganic Contaminants

Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc

All samples collected in 2007 from Clear Creek contained copper and zinc, and 24 of 25 samples contained selenium. These trace minerals are essential to human health and to the health of other animals but may be toxic at high concentrations, occurring most often with acute ingestion but also occurring occasionally with long-term, low level consumption.[40] Concentration of copper, selenium, and zinc were far below the respective HAC_{nonca} values (Tables 2b, 2d). SALG risk assessors conclude, therefore, that eating fish from Clear Creek that contain copper, selenium, and/or zinc at concentrations similar to those observed in test samples from this water body should not result in deleterious effects on individuals' health.

In contrast to copper, selenium, and zinc, neither arsenic, nor cadmium nor lead nor mercury has a known role in mammalian physiology. All are toxic to mammalian systems. Table 2a lists arsenic concentrations reported in fish collected in 2007 from Clear Creek. Most arsenic in fish, including arsenobetaine or "fish arsenic" is organic arsenic, a form of arsenic that is virtually nontoxic to humans, in part because the human kidney easily eliminates organic arsenic from the body.[14] Nonetheless, the inorganic portion of arsenic in fish may be toxic to humans. To assess the likelihood of toxicity from consuming inorganic arsenic in fish from Clear Creek, SALG risk assessors first calculated the inorganic portion of total arsenic in the fish (using a factor of 0.1 as suggested by the USEPA) and then compared the calculated inorganic fraction to the HAC_{nonca} for inorganic arsenic. No species of fish contained inorganic arsenic that exceed or even approached the HAC_{nonca} for arsenic. Further, the HQ for inorganic arsenic in fish from Clear Creek did not approach 1.0 for any sample. Thus, consuming fish from Clear Creek that contain inorganic arsenic is unlikely to have an adverse effect on human health.

Cadmium was not present at concentrations above the RL in fish from Clear Creek, suggesting that eating fish from Clear Creek would be unlikely to result in observable adverse health effects from cadmium.

Smallmouth buffalo from Clear Creek contained measurable lead. The toxic effects of lead are primarily those of abnormal nervous system development and function, with fetuses and children the sensitive population.[22] Lead apparently does not bioconcentrate significantly in finfish. Evidence suggests that lead uptake in fish is localized in the mucous on the epidermis, the dermis, and scales so that the availability in edible portions do not pose a human health risk.[41] Nonetheless, because researchers have not yet established a threshold for the neurotoxic effects of lead and trends suggest that no such threshold exists,[42] any lead ingested in fish might have adverse effects in sensitive individuals. Assuming an initial blood lead level of less than 3 mcg/dL, the USEPA's IEUBK model predicted an increase of less than one mcg/dL in the blood lead concentration of a newborn to 84-month old child consuming 15 grams/day (3.7 ounces/week) of smallmouth buffalo from Clear Creek that contain 0.267 mg lead per kg tissue. In light of modeling results, children's blood lead levels would likely be unaffected by a weekly meal of smallmouth buffalo from Clear Creek.

No fish species from Clear Creek contained mercury in excess of the HAC_{nonca} for methylmercury, the toxicant of interest in fish, nor did the HQ for mercury in any species of fish from Clear Creek exceed 1.0. These data indicate that consumption of fish from Clear Creek that contain mercury at concentrations similar to those in the 2007 samples is unlikely to result in adverse health outcomes.

Organic Contaminants

Pesticides

The laboratory reported the presence of trace to low levels of several pesticides in fish collected in 2007 from Clear Creek (Tables 3a-3e). Not all fish contained all observed pesticides. No pesticide occurred at an average concentration that exceeded its HAC_{nonca} value. No pesticide generated a hazard quotient greater than 1.0. These risk calculation results indicated that consumption of any single pesticide in fish from Clear Creek should not increase the likelihood of systemic adverse events in individuals who eat these fish.

SVOCs

Reported in eight of 25 samples, bis (2-ethylhexyl) phthalate (DEHP) was the only analyte measured at a concentration above the laboratory reporting limit. Di-n-butyl phthalate (DBP) and 2-methylnaphthalene were detected (estimated concentrations) in some of the samples (data not presented). Consuming small quantities of DEHP, DBP (both are used as plasticizers), or 2-methylnaphthalene – used to manufacture alkyl-naphthalenesulfonates, vitamin K, and the insecticide carbaryl – in Clear Lake fish will likely neither cause nor contribute to adverse systemic health effects in people who consume those fish.

VOCs

The GERG laboratory reported several VOCs in the Clear Creek fish. Most, if not all, were present only at trace levels (data not presented). VOCs in water may be present in fish from the water body. If so, the fish tissue concentration will be at equilibrium with the VOC concentration in the water. Thus, VOCs in fish may be a harbinger of contaminants in the ambient waters. Although VOCs reported in this study of fish from Clear Creek could have been present in the water, normal cellular activities also produce trace quantities of some VOCs; some may be products of tissue necrosis or decomposition. Most important to this project, all reported VOCs in the Clear Creek samples occurred at concentrations below HAC_{nonca} concentrations (data not presented). No VOC reported in the 2007 Clear Creek samples generated a HQ greater than 1.0 The SALG therefore concludes that consuming fish from Clear Creek containing trace quantities of a reported VOC is unlikely to cause adverse systemic effects on human health.

.

PCBs

All 25 samples contained measurable PCB congeners (Table 4b), although no sample contained all 209 possible congeners (data not shown). Using the 43 most prevalent, toxic, and persistent PCB congeners,[11,13,17,18] the SALG determined total PCB concentration in each sample from Clear Creek. From these calculations, SALG risk assessors calculated the average PCB concentration in each species at each site. Ultimately, the SALG determined that sampling site was immaterial to overall conclusions about the possibility of toxicity of from consuming PCBs in fish from Clear Creek. Thus, to determine the likelihood of adverse health outcomes from eating fish from Clear Creek that contain PCBs, the SALG assessed PCB concentrations in different species without regard to sampling site.

The average concentration of PCBs in flathead catfish (0.016 mg/kg), blue catfish (0.030±0.006 mg/kg), and common carp (0.036±0.011 mg/kg) did not exceed the HAC_{nonca} for PCBs (Table 4b) nor did HQs for PCBs in these species exceed 1.0 (Table 5). The SALG concluded that, because only one flathead catfish was collected from Clear Creek in 2007, the risk from regular consumption of PCBs in this species is unknown. Further, catfish of all species are covered under a consumption advisory for Galveston Bay and its contiguous waters – of which Clear Creek is one such water body – that suggests people eat catfish from those waters sparingly.

The average concentration of PCBs in blue catfish did not exceed the HAC_{nonca} for PCBs. The variation in PCB concentration in blue catfish, on the other hand, implies people could conceivably catch and eat blue catfish containing PCBs at concentrations greater than 95% of the average concentration – levels that would exceed the HAC_{nonca} for PCBs. Thus, subsistence fishers and others who eat large amounts of blue catfish could consume PCBs in that species at levels that exceed the HAC_{nonca}. People should limit consumption of blue catfish from Clear Creek to recommended meals, meal sizes, and/or recommended schedule (approximately 1 eight-ounce meal per week for adults). On the other hand, blue catfish and all other catfish species from Galveston Bay and its contiguous waters – of which Clear Creek is one – are under a consumption advisory that limits consumption of catfish of any species to no than one eight-ounce meal per month.

PCBs in four species (alligator gar, smallmouth buffalo, longnose gar, and channel catfish) exceeded the systemic HAC_{nonca} for PCBs. HQs for these four species, respectively, were 9, 5.1, 4.5, and 1.0. Allowable meals per week were 0.1, 0.2, 0.2, and 0.9, respectively. The single alligator gar collected from Clear Creek in 2007 contained PCBs at a level almost 10 times the systemic HAC_{nonca} for PCBs (0.047 mg/kg). The HQ for PCBs in this sample was 9.0; the weekly meal consumption limit was 0.1. Smallmouth buffalo and longnose gar contained PCBs at concentrations approximately five times the HAC_{nonca} for PCBs, with resultant HQs of 5.1 and 4.5, respectively. The corresponding meal consumption limits were 0.2 for both smallmouth buffalo and longnose gar. Based on these findings, people should refrain from eating gar species, smallmouth buffalo, and channel catfish from Clear Creek.

PCBs in all 25 samples averaged 0.100 mg/kg or approximately twice the HAC_{nonca} for PCBs. The resultant HQ for all species combined was 2.1, with a calculated limit of 0.4 meals per week. The SALG concludes that people could not consistently eat a diet of mixed species of freshwater fish because species containing higher PCB concentrations would likely be included in that diet.

Characterization of Theoretical Lifetime Excess Cancer Risk from Consumption of Fish from Clear Creek

Inorganic Contaminants

Arsenic, Cadmium, Copper, Lead, Mercury, Selenium, and Zinc

Inorganic arsenic is a known human carcinogen. In fish from Clear Creek, calculated concentrations of inorganic arsenic did not exceed the HAC_{ca} for inorganic arsenic. No fish sample or fish species at any site contained inorganic arsenic at concentrations that would likely increase the calculated excess lifetime risk of cancer from daily exposure for 30 years to inorganic arsenic. Thus, exposure to inorganic arsenic in fish from Clear Creek is unlikely to pose a significant risk for cancer in those who eat these fish.

CPFs (CSFs) are not available for cadmium, copper, lead, mercury, selenium, or zinc. Thus, the SALG was unable to determine the probability of excess cancers from consuming fish from Clear Creek that contain cadmium, copper, lead, mercury, selenium, or zinc. It is important to note, however, that copper, selenium, and zinc – at appropriate intake levels – are essential trace elements, necessary for health.[40] Selenium, in particular, was the subject of an observational study that showed it to have protective effects from certain human cancers, including prostate and colon cancers.[43] However, the most recent study, a randomized double-blind experimental study reported that selenium supplementation did not protect men from prostate cancer.[44]

Organic Contaminants

Pesticides

The GERG laboratory reported most fish from Clear Creek to contain pesticides, the list of which included pentachlorobenzene, hexachlorobenzene, heptachlor epoxide, chlordane, methoxychlor, and others (Tables 3a-3e), most at trace levels. Pentachlorobenzene and methoxychlor have no CSF. The SALG is thus unable to derive a quantitative theoretical risk of excess cancers from exposure to methoxychlor and pentachlorobenzene. The average concentration of each pesticide for which a theoretical excess lifetime cancer estimate was calculated was far lower than concentrations needed to increase cancer risk in those who consume the fish as shown by the fact that no observed pesticide exceeded its respective HAC_{ca} value. The SALG therefore concludes that, accepting the limitation of small sample numbers for each species, consumption of fish from Clear Creek that contain traces of one or more pesticides but that do not contain PCBs would be unlikely to increase substantially the risk of excess cancers in those who eat these fish.

VOCs

The GERG laboratory also analyzed fish from Clear Creek for VOCs. The laboratory reported all 25 fish tissue samples from Clear Creek to contain measurable concentrations of one or more VOCs. Among those VOCs reported were methylene chloride, carbon disulfide, toluene, naphthalene, benzene, chloromethane, vinyl chloride, acetone, and others (see Results for a total listing; data not shown in tables). The reported volatile organic compounds in fish tissue samples from Clear Creek occurred at concentrations well below their respective HAC_{ca} concentrations (data not presented). Predicted excess cancer incidences calculated from mean concentrations of measured VOCs were each less than one excess cancer per 10,000 equivalently exposed individuals. This finding suggests that consumption of fish from Clear Creek containing one or more of the reported VOCs at levels similar to those in the 2007 samples is unlikely to increase or to contribute to an increase in the calculated theoretical excess lifetime risk of cancer.

SVOCs

Eight fish collected in 2007 from Clear Creek contained measurable quantities of DEHP, a probable human carcinogen.[45]. However, the concentrations of DEHP in fish from Clear Creek did not exceed the HAC_{ca} for this compound (data not shown). Consuming DEHP in Clear Creek fish is unlikely to increase the likelihood of excess cancers to a level above one excess cancer in 10,000 equivalently exposed people, the cutoff point above which the DSHS may issue consumption advice for people eating fish containing a carcinogen. Some Clear Creek samples also contained DBP and/or 2-methylnaphthalene at concentrations below the RL. The USEPA has determined that DBP and 2-methylnaphthalene are "not classifiable as to carcinogenicity."[46,47] The agency consequently has published no CSF for DBP or 2-methylnaphthalene. The SALG was thus unable to calculate a theoretical risk estimate for DBP or 2-methylnaphthalene; the two contaminants, however, were observed only at concentrations below the RL. Therefore, the SALG concludes that consumption of fish from Clear Creek that contain small quantities of DEHP, DBP, and/or 2-methylnaphthalene likely will neither cause nor contribute to increases in the theoretical excess lifetime cancer risk even if people consumed the fish for up to 30 years.

PCBs

Table 6 outlines calculated probability of excess cancers from regular, long-term or repeated consumption of one or more fish species from Clear Creek. The table contains the calculated probability of one excess cancer in a given number of people exposed to PCBs in the various fish species. Of the fish sampled from Clear Creek, the concentration of PCBs in alligator gar exceeds a 1 in 10,000 calculated theoretical lifetime excess cancer risk (Table 6), meaning that only alligator gar (one sample collected) contained PCBs at a concentration that might cause or contribute to cancer in people who regularly consume this species from Clear Creek. Although other species from Clear Creek do not contain PCBs at levels that pose a carcinogenic risk, smallmouth buffalo, longnose gar, and channel catfish do contain these contaminants at concentrations already judged to pose a risk to health from systemic adverse health outcomes from long-term, low-level consumption of PCBs.

Characterization of Calculated Cumulative Systemic Health Effects and of Cumulative Excess Lifetime Cancer Risk from Consumption of Fish from Clear Creek

Cumulative systemic effects of toxicants may occur if more than one contaminant acts upon the same target organ or acts by the same mode or mechanism of action. Chlorinated pesticides and PCBs in Clear Creek fish could have these properties, especially with respect to effects on the liver. The SALG calculated cumulative effects for systemic toxicity by adding the HQs for pesticides listed in Tables 3a-3d to derive a HI for combined pesticides. Combined, pesticides in the Clear Creek samples—most observed at trace levels—did not increase the likelihood of systemic adverse health outcomes from consuming any species of fish from Clear Creek (data not shown). The SALG also assessed the probability of cumulative systemic effects of combined PCBs and chlorinated pesticides. Combining PCBs and pesticides did not increase the likelihood of adverse systemic health outcomes in any species to a magnitude greater than that for PCBs alone (data not shown). The SALG also queried probability of increasing lifetime excess cancer risk from consuming fish containing pesticides or PCBs and pesticides. Neither condition increased the calculated lifetime excess cancer risk to a risk significantly larger than that of PCBs alone in these fish (data not shown).

CONCLUSIONS

SALG risk assessors prepare risk characterizations to determine public health hazards from consumption of fish and shellfish harvested from Texas water bodies by recreational or subsistence fishers. If necessary, SALG may suggest strategies for reducing risk to the health of those who may eat contaminated fish or seafood to risk managers at DSHS, including the Texas Commissioner of Health.

This study addressed the public health implications of consuming several freshwater fish species from Clear Creek, located in Harris County, Texas, and surrounding counties. Risk assessors from the SALG conclude from this risk characterization of the data from the 2007 Clear Creek freshwater fish tissue samples

1. That channel catfish (n=7), smallmouth buffalo (n=4), and gar species (n= 3) collected from Clear Creek in 2007 contain PCBs at concentrations exceeding the PCB HAC_{nonca}. Consuming channel catfish, smallmouth buffalo, longnose gar, or alligator gar from Clear Creek **poses an apparent hazard to human health.**

2. That blue catfish and common carp contain PCBs at average concentrations approaching the PCB HAC_{nonca}. Thus, regularly consuming blue catfish or common carp from Clear Creek **may pose a hazard to human health.**

3. That the single flathead catfish from Clear Creek did not contain PCBs or other contaminants in excess of HAC values for observed contaminants. Characterization of risks to health from concentrations of observed contaminants in the single flathead catfish from Clear Creek is, thus, difficult or impossible. For this reason, the SALG characterizes the likelihood of adverse health effects from regular consumption of flathead catfish from Clear Creek as of **unknown significance to human health.**

4. That four of eight freshwater species collected from Clear Creek in 2007 (alligator gar, longnose gar, channel catfish, smallmouth buffalo) contained PCBs at an average concentration of 0.23 mg/kg – 5 times the PCB HAC_{nonca}. Three species (blue catfish, common carp, and flathead catfish) contained an average of 0.027 mg/kg PCBs – levels approximately 60% of the PCB HAC_{nonca}. The average concentration of PCBs in all samples (eight species) was 0.100 mg/kg – more than twice the PCB HAC_{nonca}. Regular consumption of a diet of mixed freshwater species from Clear Creek could thus **pose a hazard to human health.**

Under certain environmental conditions, Clear Creek is tidally influenced and under this influence, saltwater fish species from Clear Lake and/or Galveston Bay migrate into Clear Creek. At the time of the 2007 collection, however, freshwater conditions prevailed in Clear Creek. The SALG did not find saltwater species available for collection during the 2007 survey of Clear

Creek. Clear Creek is, nevertheless, contiguous with Galveston Bay. Presently, Galveston Bay and its contiguous waters are under a consumption advisory (ADV-35) for spotted seatrout and all species of catfish. The extant advisory suggests that adult men and women past childbearing should limit their consumption of spotted seatrout and catfish of any species to no more than one eight-ounce meal per month. The advisory specifically indicates that children under 12 years of age, women who are pregnant or who may become pregnant, and women who are nursing an infant should not eat fish from Galveston Bay and its contiguous waters.

RECOMMENDATIONS

Risk managers at the DSHS have established criteria for issuing fish consumption advisories based on approaches suggested by the USEPA.[11, 13, 48] Risk managers at the DSHS may decide to take some action to protect public health if a risk characterization confirms that people can eat four, or fewer meals per month (adults: eight ounces per meal; children: four ounces per meal) of fish or shellfish from a water body under investigation. Risk management recommendations may be in the form of consumption advice or a ban on possession of fish from the affected water body. Fish or shellfish possession bans are enforceable under subchapter D of the Texas Health and Safety Code, part 436.061(a).[49] Declarations of prohibited harvesting areas are enforceable under the Texas Health and Safety Code, Subchapter D, parts 436.091 and 436.101.[49] DSHS consumption advice carries no penalty for noncompliance. Consumption advisories, instead, inform the public of potential health hazards associated with consuming contaminated fish or shellfish from Texas waters. With this information, members of the public can make informed decisions about whether and/or how much – contaminated fish or shellfish they wish to consume. The SALG concludes from this risk characterization that consuming catfish, gar species, or longnose gar from Clear Creek **poses an apparent hazard to public health.** Therefore, SALG risk assessors recommend

1. That pregnant women, women who may become pregnant, women who are nursing an infant, and children 12 years of age or under or who weigh less than 75 pounds should not eat any species of fish from Clear Creek because consuming PCBs may result in adverse effects on the developing nervous system.

2. That adult men and women past childbearing should not eat catfish species, gar species, or smallmouth buffalo from Clear Creek because these fish may contain PCBs at levels that could result in adverse systemic health outcomes.

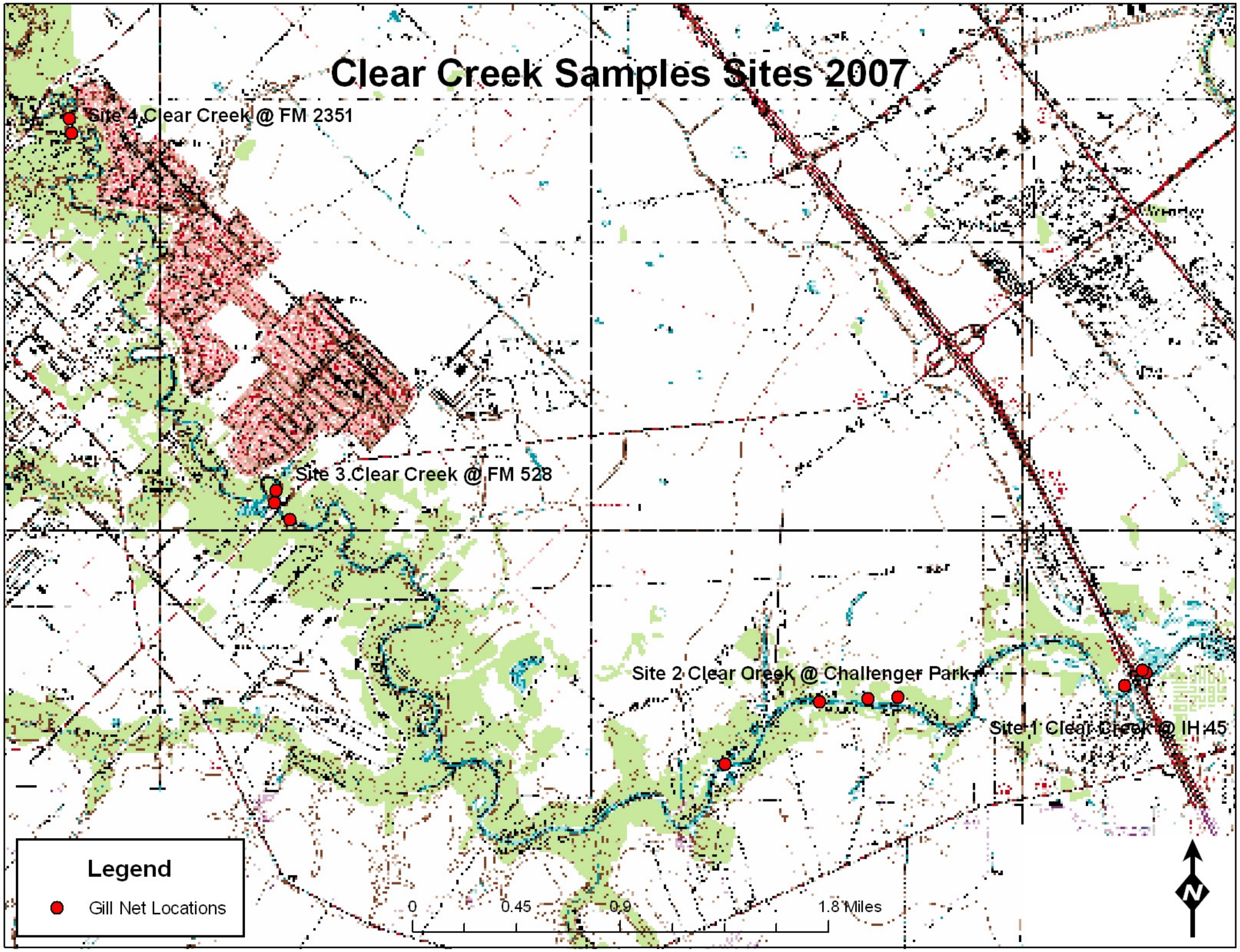
3. That adult men and women past childbearing should not consume a diet of mixed freshwater and/or saltwater fish from Clear Creek because regularly consuming a diet consisting of mixed freshwater species or fresh- or saltwater catfish from Clear Creek could expose them to PCB concentrations that could result in adverse health outcomes.

4. That the DSHS should continue to monitor freshwater species from Clear Creek for chemical contamination. The agency should return to Clear Creek under environmental conditions conducive to collecting saltwater species to assess chemical contaminants in saltwater fish found in Clear Creek upstream of its outflow into Clear Lake.

PUBLIC HEALTH ACTION PLAN

Communication to the public of new and continuing possession bans or consumption advisories, or the removal of either, is essential to effective management of risk from consuming contaminated fish. In fulfillment of the responsibility for communication, the Texas Department of State Health Services (DSHS) takes several steps. The agency publishes fish consumption advisories and bans in a booklet available to the public through the Seafood and Aquatic Life Group (SALG). To receive the booklet and/or the data, please contact the SALG at 1-512-834-6757.[50] The SALG also posts the most current information about advisories, bans, and the removal of either on the internet at http://www.dshs.state.tx.us/seafood. The SALG regularly updates this Web site. The DSHS also provides USEPA (http://epa.gov/waterscience/fish/advisories/), the TCEQ (http://www.tceq.state.tx.us), and the Texas Parks and Wildlife Department (TPWD) (http://www.tpwd.state.tx.us) with information on all consumption advisories and possession bans. Each year, the TPWD informs the fishing and hunting public of consumption advisories and fishing bans on it's Web site and in an official hunting and fishing regulations booklet available at many state parks and at all establishments selling Texas fishing licenses.[51] Readers may direct questions about the scientific information or recommendations in this risk characterization to the SALG at 512-834-6757 or may find the information at the SALG's Web site (http://www.dshs.state.tx.us/seafood). Secondarily, one may address inquiries to the Environmental and Injury Epidemiology and Toxicology Branch of the Department of State Health Services (512-458-7269). The USEPA's IRIS Web site (http://www.epa.gov/iris/) contains information on environmental contaminants found in food and environmental media. The Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology (888-42-ATSDR or 888-422-8737) or the ATSDR's Web site (http://www.atsdr.cde.gov) supplies brief information via ToxFAQs.™ ToxFAQs™ are available on the ATSDR Web site in either English (http://www.atsdr.cdc.gov/toxfaq.html) or Spanish (http://www.atsdr.cdc.gov/es/toxfaqs/es _toxfaqs.html). The ATSDR also publishes more in-depth reviews of many toxic substances in its *Toxicological Profiles* (ToxProfiles™). To request a copy of the ToxProfiles™ CD-ROM, PHS, or ToxFAQs™ call 1-800-CDC-INFO (800-232-4636) or email a request to cdcinfo@cdc.gov.

Figure 1. Clear Creek Sample Sites



TABLES

Table 1. Fish samples collected from Clear Creek on April 2 through April 5, 2007. Sample number, species, length, and weight were recorded for each sample.

Sample Number	Species	Length (mm)	Weight (g)
Site 1 Clear Creek @ IH 45			
CLC12	Blue catfish	621	2517
CLC13	Blue catfish	520	1647
CLC14	Channel catfish	623	2706
CLC15	Flathead catfish	631	2745
CLC16	Smallmouth buffalo	640	5464
CLC18	Common carp	610	2864
CLC19	Common carp	621	3227
CLC20	Alligator gar	897	5072
Site 2 Clear Creek @ Challenger Park			
CLC1	Smallmouth buffalo	642	5066
CLC3	Channel catfish	587	2219
CLC5	Blue catfish	543	1740
CLC6	Blue catfish	490	1317
CLC7	Channel catfish	570	1937
CLC8	Blue catfish	487	1298
CLC9	Common carp	705	4109
CLC10	Common carp	685	4040
CLC11	Longnose gar	902	3029
Site 3 Clear Creek @ FM 528			
CLC21	Channel catfish	620	2929
CLC22	Channel catfish	704	4944
CLC24	Channel catfish	510	1571
CLC25	Blue catfish	489	1306
CLC26	Smallmouth buffalo	635	5075
CLC28	Longnose gar	945	2906
Site 4 Clear Creek @ FM 2351			
CLC29	Channel catfish	544	1840
CLC30	Smallmouth buffalo	449	1397

Table 2a. Arsenic (mg/kg) in fish collected from Clear Creek, 2007.					
Species	**# Detected/ # Sampled**	**Total Arsenic Mean Concentration ± S.D. (Min-Max)**	**Inorganic Arsenic Mean Concentration[e]**	**Health Assessment Comparison Value (mg/kg)[f]**	**Basis for Comparison Value**
Alligator gar	1/1	0.058	0.006	0.7 0.362	EPA chronic oral RfD for Inorganic arsenic: 0.0003 mg/kg–day EPA oral slope factor for inorganic arsenic: 1.5 per mg/kg–day
Blue catfish	6/6	0.053±0.023 (BDL[g]-0.073)	0.005		
Channel catfish	7/7	0.092±0.052 (BDL-0.170)	0.009		
Common carp	4/4	0.104±0.043 (0.049-0.154)	0.010		
Flathead catfish	1/1	0.034	0.003		
Longnose gar	2/2	0.441±0.168 (0.322-0.559)	0.044		
Smallmouth buffalo	4/4	0.266±0.209 (BDL-0.519)	0.027		
All fish combined	25/25	0.136±0.146 (BDL-0.559)	0.014		

[e] *Most arsenic in fish and shellfish occurs as organic arsenic, considered virtually nontoxic. For risk assessment calculations, DSHS assumes that total arsenic is composed of 10% inorganic arsenic in fish and shellfish tissues.*

[f] *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 $1x10^{-4}$.*

[g] *BDL: "Below Detection Limit" – Concentrations were reported as less than the laboratory's method detection limit ("J" values). In some instances, a "J" value was used to denote the discernable presence in a sample of a contaminant at concentrations estimated as different from the sample blank*

Table 2b. Inorganic contaminants (mg/kg) in fish collected from Clear Creek, 2007.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Cadmium				
Alligator gar	1/1	BDL	0.47	ATSDR chronic oral MRL: 0.0002 mg/kg–day
Blue catfish	4/6	BDL		
Channel catfish	6/7	BDL		
Common carp	3/4	BDL		
Flathead catfish	1/1	BDL		
Longnose gar	1/2	BDL		
Smallmouth buffalo	4/4	BDL		
All fish combined	20/25	BDL		
Copper				
Alligator gar	1/1	BDL	333	National Academy of Science Upper Limit: 0.143 mg/kg–day
Blue catfish	6/6	0.230±0.062 (0.165-0.339)		
Channel catfish	7/7	0.282±0.183 (0.162-0.688)		
Common carp	4/4	0.549±0.154 (0.399-0.761)		
Flathead catfish	1/1	0.163		
Longnose gar	2/2	0.168±0.076 (0.114-0.222)		
Smallmouth buffalo	4/4	0.503±0.171 (0.274-0.663)		
All fish combined	25/25	0.324±0.197 (BDL-0.761)		

Table 2c. Inorganic contaminants (mg/kg) in fish collected from Clear Creek, 2007.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Lead				
Alligator gar	1/1	BDL	0.6	EPA IEUBKwin
Blue catfish	5/6	BDL		
Channel catfish	6/7	BDL		
Common carp	3/4	BDL		
Flathead catfish	0/1	ND		
Longnose gar	2/2	BDL		
Smallmouth buffalo	3/4	0.108±0.106 (ND-0.267)		
All fish combined	20/25	0.051±0.045 (ND-0.267)		
Mercury				
Alligator gar	1/1	0.261	0.7	ATSDR chronic oral MRL: 0.0003 mg/kg–day
Blue catfish	6/6	0.080±0.038 (0.056-0.157)		
Channel catfish	7/7	0.065±0.053 (BDL-0.166)		
Common carp	4/4	0.037±0.020 (BDL-0.057)		
Flathead catfish	1/1	0.086		
Longnose gar	2/2	0.172±0.004 (0.169-0.175)		
Smallmouth buffalo	4/4	0.115±0.068 (BDL-0.174)		
All fish combined	25/25	0.089±0.065 (BDL-0.261)		

Table 2d. Inorganic contaminants (mg/kg) in fish collected from Clear Creek, 2007.				
Species	**# Detected/ # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Selenium				
Alligator gar	1/1	0.073	6	EPA chronic oral RfD: 0 .005 mg/kg–day ATSDR chronic oral MRL: 0.005 mg/kg–day NAS UL: 0.400 mg/day (0.005 mg/kg–day) RfD or MRL/2: (0.005 mg/kg –day/2= 0.0025 mg/kg–day) to account for other sources of selenium in the diet
Blue catfish	6/6	0.160±0.035 (0.117-0.221)		
Channel catfish	6/7	0.117±0.054 (ND-0.172)		
Common carp	4/4	0.272±0.102 (0.203-0.424)		
Flathead catfish	1/1	0.201		
Longnose gar	2/2	0.246±0.107 (0.170-0.321)		
Smallmouth buffalo	4/4	0.216±0.105 (0.094-0.328)		
All fish combined	24/25	0.180±0.089 (ND-0.424)		
Zinc				
Alligator gar	1/1	1.939	700	EPA chronic oral RfD: 0.3 mg/kg–day
Blue catfish	6/6	4.576±1.370 (3.108-6.392)		
Channel catfish	7/7	5.162±0.902 (3.419-5.917)		
Common carp	4/4	5.831±1.177 (4.475-7.019)		
Flathead catfish	1/1	4.342		
Longnose gar	2/2	3.481±0.146 (3.378-3.584)		
Smallmouth buffalo	4/4	3.804±0.124 (3.709-3.982)		
All fish combined	25/25	4.615±1.274 (1.939-7.019)		

Table 3a. Pesticides (mg/kg) in fish collected from Clear Creek, 2007				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Pentachlorobenzene				
Alligator gar	1/1	0.001	1.867	EPA chronic oral RfD: 0.0008 mg//kg–day no slope factor available
Blue catfish	6/6	0.0004±0.0002 (BDL-0.0008)		
Channel catfish	7/7	0.0007±0.0004 (BDL-0.001)		
Common carp	4/4	0.0005±0.0002 (BDL-0.0007)		
Flathead catfish	1/1	BDL		
Longnose gar	2/2	0.0006±0.0005 (BDL-0.0009)		
Smallmouth buffalo	4/4	0.003±0.0008 (0.002-0.003)		
All fish combined	25/25	0.001±0.00097 (BDL-0.003)		
Hexachlorobenzene				
Alligator gar	1/1	0.002	1.867 0.34	EPA chronic oral RfD: 0.0008 mg//kg–day EPA slope factor: 16 per mg/kg-day
Blue catfish	6/6	0.0005±0.0003 (BDL-0.001)		
Channel catfish	6/7	0.0006±0.0005 (ND-0.002)		
Common carp	4/4	0.0005±0.0003 (BDL-0.0008)		
Flathead catfish	1/1	BDL		
Longnose gar	2/2	0.0009±0.0005 (0.0006-0.001)		
Smallmouth buffalo	4/4	0.004±0.002 (0.002-0.007)		
All fish combined	24/25	0.001±0.002 (ND-0.007)		

Table 3b. Pesticides (mg/kg) in fish collected from Clear Creek, 2007				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Heptachlor epoxide				
Alligator gar	1/1	0.003	0.03 0.06	EPA chronic oral RfD: 0.000013 mg//kg–day EPA slope factor: 9.1 per mg/kg-day
Blue catfish	5/6	0.001±0.0007 (ND-0.002)		
Channel catfish	6/7	0.001±0.0008 (ND-0.002)		
Common carp	2/4	0.0009±0.0009 (ND-0.002)		
Flathead catfish	0/1	ND		
Longnose gar	2/2	0.0009±0.0009 (BDL-0.002)		
Smallmouth buffalo	4/4	0.004±0.002 (0.002-0.005)		
All fish combined	20/25	0.002±0.001 (ND-0.005)		
Chlordane				
Alligator gar	1/1	0.337	1.167 1.553	EPAchronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.35 per mg/kg–day
Blue catfish	6/6	0.019±0.012 (0.009-0.040)		
Channel catfish	7/7	0.021±0.016 (BDL-0.050)		
Common carp	4/4	0.030±0.034 (0.007-0.080)		
Flathead catfish	1/1	0.006		
Longnose gar	2/2	0.051±0.053 (0.014-0.089)		
Smallmouth buffalo	4/4	0.113±0.096 (0.016-0.233)		
All fish combined	25/25	0.051±0.079 (BDL-0.337)		

Table 3c. Pesticides (mg/kg) in fish collected from Clear Creek, 2007				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
2,4'-DDD				
Alligator gar	1/1	0.005	2.265	no RfD available EPA slope factor: 0.24 per mg/kg-day
Blue catfish	6/6	0.0009±0.0005 (BDL-0.002)		
Channel catfish	6/7	0.001±0.0009 (ND-0.003)		
Common carp	4/4	0.002±0.001 (0.0006-0.003)		
Flathead catfish	1/1	BDL		
Longnose gar	1/2	0.003±0.0033 (ND-0.005)		
Smallmouth buffalo	4/4	0.009±0.005 (0.003-0.015)		
All fish combined	23/25	0.003±0.004 (ND-0.015)		
Methoxychlor				
Alligator gar	0/1	ND	11.67	EPA chronic oral RfD: 0.005 mg//kg–day no slope factor available
Blue catfish	5/6	0.064±0.040 (ND-0.130)		
Channel catfish	6/7	0.087±0.053 (ND-0.191)		
Common carp	3/4	0.034±0.023 (ND-0.056)		
Flathead catfish	0/1	ND		
Longnose gar	2/2	0.029±0.020 (BDL-0.043)		
Smallmouth buffalo	4/4	0.136±0.053 (0.085-0.201)		
All fish combined	20/25	0.070±0.054 (ND-0.201)		

Table 3d. Pesticides (mg/kg) in fish collected from Clear Creek, 2007				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
4,4' DDE				
Alligator gar	1/1	0.299	1.167 1.599	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.34 per mg/kg - day
Blue catfish	6/6	0.004±0.001 (0.003-0.006)		
Channel catfish	7/7	0.006±0.004 (0.001-0.014)		
Common carp	4/4	0.014±0.010 (0.003-0.026)		
Flathead catfish	1/1	0.002		
Longnose gar	2/2	0.034±0.045 (0.002-0.066)		
Smallmouth buffalo	4/4	0.030±0.026 (0.006-0.064)		
All fish combined	25/25	0.025±0.060 (0.001-0.299)		
4,4' DDD				
Alligator gar	1/1	0.030	1.167 2.27	EPA chronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.24 per mg/kg–day
Blue catfish	6/6	0.002±0.001 (0.001-0.004)		
Channel catfish	7/7	0.002±0.0016 (0.0007-0.005)		
Common carp	4/4	0.003±0.002 (0.001-0.005)		
Flathead catfish	1/1	0.0005		
Longnose gar	2/2	0.007±0.0001 (0.007-0.008)		
Smallmouth buffalo	4/4	0.010±0.007 (0.004-0.019)		
All fish combined	25/25	0.005±0.007 (0.0005-0.030)		

Table 3e. Pesticides (mg/kg) in fish collected from Clear Creek, 2007				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
2,4' DDT				
Alligator gar	1/1	0.004	1.167 1.578	EPAchronic oral RfD: 0.0005 mg//kg–day EPA slope factor 0.34 per mg/kg - day
Blue catfish	6/6	0.0017±0.0017 (0.0005-0.005)		
Channel catfish	7/7	0.0019±0.002 (BDL-0.006)		
Common carp	4/4	0.0018±0.0019 (BDL-0.004)		
Flathead catfish	1/1	BDL		
Longnose gar	2/2	0.006±0.007 (0.0008-0.011)		
Smallmouth buffalo	4/4	0.002±0.001 (0.001-0.004)		
All fish combined	25/25	0.0022±0.0024 (BDL-0.011)		

Table 4a. PCBs (mg/kg) in fish collected from Clear Creek, 2007.

Species	# Detected / # Sampled	Mean Concentration ± S.D. (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 IH 45				
Alligator gar	1/1	**0.418***	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Blue catfish	2/2	0.026±0.004 (0.023-0.029)		
Channel catfish	1/1	**0.061**		
Common carp	2/2	0.040±0.007 (0.035-0.045)		
Flathead catfish	1/1	0.016		
Smallmouth buffalo	1/1	**0.676**		
All fish combined	8/8	**0.163**±0.247 (0.016-**0.676**)		
Site 2 Challenger Park				
Blue catfish	3/3	0.032±0.008 (0.023-0.039)	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Channel catfish	2/2	0.021±0.014 (0.011-0.031)		
Common carp	2/2	0.032±0.015 (0.021-0.043)		
Longnose gar	1/1	**0.404**		
Smallmouth buffalo	1/1	**0.075**		
All fish combined	9/9	**0.076**±0.125 (0.011-**0.404**)		
Site 3 FM 528				
Blue catfish	1/1	0.030	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Channel catfish	3/3	**0.065**±0.048 (0.030-**0.119**)		
Longnose gar	1/1	0.017		
Smallmouth buffalo	1/1	**0.189**		
All fish combined	6/6	**0.072**±0.068 (0.017-**0.189**)		

* Emboldened numbers denote concentrations of PCBs that exceed the HAC_{nonca} for Aroclor 1254

Table 4b. PCBs (mg/kg) in fish collected from Clear Creek, 2007.				
Species	**# Detected / # Sampled**	**Mean Concentration ± S.D. (Min-Max)**	**Health Assessment Comparison Value (mg/kg)**	**Basis for Comparison Value**
Site 4 FM 2351				
Channel catfish	1/1	**0.054**	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Smallmouth buffalo	1/1	0.023		
All fish combined	2/2	0.038±0.022 (0.023-**0.054**)		
All Sites				
Alligator gar	1/1	**0.418***	0.047 0.272	EPA chronic oral RfD: 0.00002 mg/kg–day EPA slope factor: 2.0 per mg/kg–day
Blue catfish	6/6	0.030±0.006 (0.023-0.039)		
Channel catfish	7/7	**0.050**±0.035 (0.011-**0.119**)		
Common carp	4/4	0.036±0.011 (0.021-0.045)		
Flathead catfish	1/1	0.016		
Longnose gar	2/2	**0.211**±0.274 (0.017-**0.404**)		
Smallmouth buffalo	4/4	**0.241**±0.298 (0.023-**0.676**)		
All fish combined	25/25	**0.100**±0.161 (0.011-**0.676**)		

* Emboldened numbers denote concentrations of PCBs that exceed the HAC_{nonca} for Aroclor 1254

Table 5. Hazard quotients (HQ) for PCBs in fish collected from Clear Creek in 2007. Table 5 also provides suggested weekly eight-ounce meal consumption rates for 70-kg adults.		
Species	**Hazard Quotient**	**Meals per Week**
Alligator gar	**9.0***	**0.1†**
Blue catfish	0.6	1.4
Channel catfish	**1.0**	**0.9**
Common carp	0.7	1.2
Flathead catfish	0.3	2.7
Longnose gar	**4.5**	**0.2**
Smallmouth buffalo	**5.1**	**0.2**
All fish combined	**2.1**	**0.4**

* Emboldened numbers denote the HQ for PCBs exceeds 1.0
† Emboldened numbers denote the calculated allowable meal consumption rate for an adult is less than one/week.

Table 6. Calculated theoretical lifetime excess cancer risk from consuming fish containing PCBs collected in 2007 from Clear Creek and suggested consumption (8-ounce meals/week) for 70 kg adults who regularly eat fish from Clear Creek over a 30-Year Period. [h]

Species	Theoretical Lifetime Excess Cancer Risk		Meals per Week
	Risk	1 excess cancer per number of people exposed	
Alligator gar	**1.54E-04***	**6,512**	**0.6**†
Blue catfish	1.10E-05	90,741	8.3
Channel catfish	1.84E-05	54,444	5.0
Common carp	1.32E-05	75,617	6.9
Flathead catfish	5.88E-06	170,139	15.7
Longnose gar	7.75E-05	12,902	1.2
Smallmouth buffalo	8.85E-05	11,296	1.0
Average of all fish, assuming equal consumption	3.67E-05	27,222	2.5
Average of all fish other than alligator gar, assuming equal consumption	3.18E-05	31,485	2.9

* Emboldened numbers denote calculated excess lifetime cancer risk after 30 years exposure is greater than 1 X 10^{-4}

† Emboldened numbers denote the calculated meal consumption rate for adults is less than one per week

[h] DSHS assumes that children under the age of 12 years and/or those who weigh less than 35 kg eat 4-ounce meals.

LITERATURE CITED

[1] Villanacci, J. Health Consultation: Health and Safety Issues Brio Oil Refinery Site Southbend Community, Friendswood, Texas. Texas Department of Health, Health Risk Assessment and Toxicology April 5, 1994.

[2] [TDH] Texas Department of Health Fish and Shellfish Consumption Advisory ADV-7 Clear Creek, November 18, 1993. http://www.dshs.state.tx.us/seafood/PDF2/Rescinded/ADV-7_signed_ClearCr.pdf (Accessed March 26, 2009).

[3] [TDH] Texas Department of Health. Seafood Safety Division (SSD). Health Consultation: Clear Creek, Harris County, Brazoria County, Galveston County. September 10, 2001.

[4] Harris County Flood Control District http://www.hcfcd.org/L_clearcreek.html (accessed September 4, 2008).

[5] U.S. Census Bureau Population Finder, Harris County, Texas http://factfinder.census.gov/servlet/SAFFPopulation?_event=Search&geo_id=05000US48313&_geoContext=01000US%7C04000US48%7C05000US48313&_street=&_county=Harris+County&_cityTown=Harris+County&_state=04000US48&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=050&_submenuId=population_0&ds_name=null&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry= (accessed September 4, 2008).

[6] The Handbook of Texas Online, Harris County, Texas. http://www.tshaonline.org/handbook/online/articles/HH/hch7.html (accessed September 4, 2008).

[7] U.S. Census Bureau Population Finder, Houston, Texas. http://factfinder.census.gov/servlet/SAFFPopulation?_event=Search&geo_id=16000US4835000&_geoContext=01000US%7C04000US48%7C16000US4845996&_street=&_county=Houston%3Bcity+of&_cityTown=Houston%3Bcity+of&_state=04000US48&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=010&_submenuId=population_0&ds_name=null&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry= (accessed September, 4 2008).

[8] http://www.epa.gov/waterscience/316b/econbenefits/b6.pdf (accessed February 24, 2009).

[9] Clean Water Act. 33 USC 125 *et seq.* 40CFR part 131: Water Quality Standards.

[10] [DSHS] Texas Department of State Health Services, Seafood and Aquatic Life Group Survey Team Standard Operating Procedures and Quality Assurance/Quality Control Manual. Austin, Texas. 2007.

[11] [USEPA] United States Environmental Protection Agency. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 1, Fish sampling and analysis, 3rd ed. Washington D.C. 2000.

[12] [TSCC] Toxic Substances Coordinating Committee URL: http://www.tscc.state.tx.us/dshs.htm (Accessed February 24, 2009).

[13] [USEPA] United States Environmental Protection Agency. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 2, Risk assessment and fish consumption limits, 3rd ed. Washington D.C. 2000.

[14] [USDHHS] United States Department of Health & Human Services. Public Health Service. [ATSDR] Agency for Toxic Substances and Disease Registry. Toxicological profile for arsenic (update). Atlanta, GA. 2007.

[15] Clean Water Act. 33 USC 125 *et seq.* 40CFR part 131: Water Quality Standards.

[16] [USDHHS] United States Department of Health & Human Services. Public Health Service. [ATSDR] Agency for Toxic Substances and Disease Registry. Toxicological Profile for Mercury (update). Atlanta, GA: 1999 March.

[17] Lauenstein, G.G. & Cantillo, A.Y. 1993. Sampling and Analytical Methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984-1992: Overview and Summary of Methods - Vol. I. NOAA Tech. Memo 71. NOAA/CMBAD/ORCA. Silver Spring, MD. 157pp. http://www.ccma.nos.noaa.gov/publications/tm71v1.pdf (Accessed February 24, 2009).

[18] McFarland, V.A. & Clarke, J.U. 1989. Environmental occurrence, abundance, and potential toxicity of polychlorinated biphenyl congeners: considerations for a congener-specific analysis. Environmental Health Perspectives. 81:225-239.

[19] [IRIS] Integrated Risk Information System, maintained by the USEPA. Polychlorinated biphenyls (PCBs) (CASRN 1336-36-3), Part II,B.3. Additional Comments (Carcinogenicity, Oral Exposure http://www.epa.gov/iris/subst/0294.htm (Accessed February 24, 2009).

[20] [IRIS] Integrated Risk Information System, maintained by the USEPA. Comparison of database information for RfDs on Aroclor® 1016, 1254, 1260 http://cfpub.epa.gov/ncea/iris/compare.cfm (Accessed on February 24, 2009).

[21] [USEPA] United States Environmental Protection Agency. Integrated Risk Information System (IRIS) for PCBs. http://www.epa.gov/ncea/iris/subst/0294.htm#quaoral (Accessed February 24, 2009).

[22] Casarett and Doull's Toxicology: The Basic Science of Poisons. 5th ed. Ed. CD Klaassen. Chapter 2, pp. 13-34. McGraw-Hill Health Professions Division, New York, NY, 1996.

[23] Beauchamp, Richard. 1999. Personal Communication. *Monte Carlo Simulations in Analysis of Fish Tissue Contaminant Concentrations and Probability of Toxicity.* Department of State Health Services, State of Texas.

[24] [USEPA] United States Environmental Protection Agency. Office of Research and Development, National Center for Environmental Assessment. Integrated risk information system (IRIS). Human Health Risk Assessments. Background Document 1A. 1993, March. http://www.epa.gov/iris/rfd.htm (Accessed February 24, 2009).

[25] [USDHHS] United States Department of Health & Human Services. Public Health Service. [ATSDR] Agency for Toxic Substances and Disease Registry. Minimal Risk Levels for Hazardous Substances. http://www.atsdr.cdc.gov/mrls/index.html (Accessed February 24, 2009).

[26] [USEPA] United States Environmental Protection Agency. Glossary of risk assessment-related terms. Washington, D.C.: 1999. http://www.epa.gov/NCEA/iris/help_gloss.htm (Accessed August 29, 2006).

[27] [USEPA] United States Environmental Protection Agency. Technology Transfer Network. National Air Toxics Assessment. Glossary of Key Terms. Washington, D.C.: 2002. http://www.epa.gov/ttn/atw/nata/gloss1.html (Accessed February 24, 2009).

[28] [USEPA] United States Environmental Protection Agency. Guidelines for Carcinogen Risk Assessment and Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. Federal Register Notice posted April 7, 2005

[29] Thompson, KM. *Changes in Children's Exposure as a Function of Age and the Relevance of Age Definitions for Exposure and Health Risk Assessment*. MedGenMed. 6(3), 2004. http://www.medscape.com/viewarticle/480733. (Accessed February 24, 2009).

[30] University of Minnesota. Maternal and Child Health Program *Healthy Generations: Children's Special Vulnerability to Environmental Health Risks*. http://www.epi.umn.edu/mch/resources/hg/hg_enviro.pdf (Accessed February 24, 2009).

[31] Selevan, SG, CA Kimmel, P Mendola. *Identifying Critical Windows of Exposure for Children's Health.* Environmental Health Perspectives Volume 108, Supplement 3, June 2000.

[32] Schmidt, C.W. *Adjusting for Youth: Updated Cancer Risk Guidelines*. Environ. Health Perspectives. 111(13):A708-A710.

[33] [USDHHS] United States Department of Health & Human Services. Public Health Service. Agency for Toxic Substances and Disease Registry (ATSDR). Office of Children's Health. Child health initiative. Atlanta Ga.: 1995.

[34] [USEPA] United States Environmental Protection Agency. Office of Research and Development (ORD). Strategy for research on environmental risks to children, Section 1.2. Washington D.C.: 2000.

[35] SPSS 13 for Windows©. Release 13.0.1. 12 December 2004. Copyright SPSS, Inc., 1989-2009. http://www.spss.com (Accessed February 24, 2009).

[37] [CDC] Centers for Disease Control and Prevention. Preventing Lead Poisoning in Young Children. Atlanta: CDC; 2005 http://www.cdc.gov/nceh/lead/publications/PrevLeadPoisoning.pdf (Accessed February 24, 2009).

*[38] [CDC] Centers for Disease Control and Prevention. Interpreting and Managing Blood Lead Levels <10 mcg/dL in Children and Reducing Childhood Exposures to Lead. MMWR, Nov 2, 2007/ 56(RR08); 1-14; 16. httm://www.cdc.gov/mmwr/preview/mmwrhtml/rr5608al.htm ERRATUM MMWR November 30, 2007 / 56(47):1241-1242. httm://www.cdc.gov/mmwr/preview/mmwrhtml/mm5647a4.htm

[39] Navy and Marine Corps Public Health Center. 2002. *Detection Limit and Reporting Limit Issues Related to Risk Assessments.* http://www-nehc.med.navy.mil/HHRA/guidancedocuments/issue/pdf/FDI.pdf (Accessed December 9, 2008).

[40] Reilly, Conor. The Nutritional Trace Metals, Chapters 3-5. Blackwell Publishing, Malden, MA 02148. 2004.

[41] [USEPA] United States Environmental Protection Agency. Ground Water and Drinking Water. Technical Factsheet on Lead. http://www.epa.gov/safewater/dwh/t-ioc/lead.html (accessed February 26, 2009).

[42] Lidsky, TI and JS Schneider. Lead neurotoxicity in children: basic mechanisms and clinical correlates. *Brain* (2003) **126**, 5-19. DOI: 10.1093/brain/awg014.

[43] Clark, L., B. Combs, E. Turnbull, D. Slate, J. Chalker, J. Chow, et al. 1996. *Effects of selenium supplementation for cancer prevention in patients with carcinoma of the skin.* Journal of the American Medical Association (JAMA), 276:1957-63. Secondary reference from Journal Club on the Web http://www.journalclub.org/vol2/a39.html (accessed September 2, 2008).

[44]Lippman, SM, EA Klein, PJ Goodman, MS Lucia and others. Effect of Selenium and Vitamin # on Risk of Prostate Cancer and Other Cancers: The Selenium and Vitamin E Cancer Prevention Trial (SELECT) *JAMA*. 2009;301(1):39-51. DOI:10:1001/jama.2008.864

[45] [IRIS] Integrated Risk Information System. Di(2-ethylhexyl)phthalate (DEHP) (CASRN 117-81-7). http://www.epa.gov/ncea/iris/subst/0014.htm (Accessed March 26, 2009)

[46][IRIS] Integrated Risk Information System Dibutyl phthalate (DBP) (CASRN 84-74-2). http://www.epa.gov/ncea/iris/subst/0038.htm (Accessed March 26, 2009).

[47] [IRIS] Integrated Risk Information System. 2-methylnaphthalene (CASRN 91-57-6) http://www.epa.gov/ncea/iris/subst/1006.htm (Accessed March 26, 2009).

[48] [USEPA] United States Environmental Protection Agency. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 3, Overview of Risk Management, Washington D.C. 1996.

[49] Texas Statutes: Health and Safety, Chapter 436, Subchapter D, § 436.011, §436.061 and others.

[50] [DSHS] Department of State Health Services for the State of Texas. Fish Consumption Advisories and Bans. Seafood Safety Division. Austin, Texas: 2004.

[51] [TPWD] Texas Parks and Wildlife Department. 2007-2008 Outdoor Annual: hunting and fishing regulations. Ed. J. Jefferson. Texas Monthly Custom Publishing, a division of Texas Monthly, Inc. 2007.