QUANTITATIVE RISK CHARACTERIZATION

Lower Leon Creek

San Antonio, Bexar County, TX

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Revisions 10/15/03, 10/23/03

Prepared by
Texas Department of Health
Seafood Safety Division
Environmental Epidemiology and Toxicology Division

BACKGROUND AND STATEMENT OF THE ISSUES

Kelly Air Force Base (Kelly AFB; Kelly; KAFB), decommissioned in 2001 under the 1995 Base Closure and Realignment Commission, was once the largest military installation in Texas. Renamed "KellyUSA," and scheduled for civilian development, the base – located on 4,000 acres in southwest San Antonio, Texas – was for half a century a major United States Air Force (USAF) aircraft maintenance station. Industrial wastes from activities conducted at KAFB are alleged to have contaminated shallow groundwater and soil in and around KAFB with organic solvents and other toxic compounds [1]. Trichloroethene (trichloroethylene; TCE) and tetrachloroethene (perchloroethylene; PCE) are among several contaminants discovered in the groundwater under the base [2]. In the early 1980's, the federal government began to examine the extent of contamination and to clean up hazardous waste generated by base activities. The USAF continues, under various federal initiatives, site monitoring and remediation efforts. In 1999, in response to petitions from area citizens concerned about possible adverse health effects from exposure to environmental contaminants attributed to base activities, the Agency for Toxic Substances and Disease Registry (ATSDR) completed a public health assessment of Kelly Air Force Base [3]. That assessment included an examination of fish from Lower Leon Creek, a small stream that meanders southeasterly through Kelly AFB in both suburban and metropolitan areas of San Antonio – the fourth largest metropolitan statistical area in Texas [4] – to the Medina River. With its shallow banks, Lower Leon Creek is easily accessible through public parks and bridge crossings, increasing the possibility that people will consume fish taken from its waters. On the other hand, this creek courses through heavily urban areas, a characteristic that may decrease the probability that people will fish there. Using techniques and assumptions that may differ from those used by the Texas Department of Health to assess exposure and characterize risk, the ATSDR concluded that exposure to toxicants in air, soil, water, and fish from around Kelly AFB should not adversely affect human health [3].

As part of its routine monitoring of environmental conditions at KAFB, the USAF collected and analyzed samples of whole fish from Lower Leon Creek at a site near the Kelly Air Force Base golf course in July 2000. That assessment confirmed that whole fish samples from Lower Leon Creek contained PCBs and organochlorine pesticides [2]. Although whole-fish samples are useful for identifying contaminants in fish and shellfish, such analyses may not accurately reflect toxicant distribution in edible tissues and may over- or underestimate exposure to environmental contaminants because people often remove the skin from fish and are more liable to consuming fillets than whole fish [5]. Therefore, the USAF collaborated with the Texas Department of Health (TDH) to assess contamination in edible portions of fish from Lower Leon Creek and to characterize possible risks to human health from consuming fish from Lower Leon Creek. To this end, the TDH Seafood Safety Division (SSD) collected fish from three sites along Lower Leon Creek in August 2002. The TDH laboratory analyzed skin-off fillets of these samples for contaminants that could potentially result in adverse effects on the health of people who eat fish from Lower Leon Creek.

METHODS

Tissue Collection and Analysis

To evaluate potential health risks to recreational and subsistence fishers who consume environmentally contaminated fish, the Seafood Safety Division (SSD) collects and analyzes tissue samples of edible fish from the state's public waters. These samples represent legal-sized species available for consumption from a given waterbody. When practical, the SSD collects samples from several sites within the waterbody to characterize the geographical distribution of contaminants. The TDH laboratory utilizes established methodology to analyze edible fillets (skin off) of fish for seven metals – arsenic[1], cadmium, copper, lead, mercury[2], selenium, and zinc – and for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs: Aroclors 1016, 1221, 1224, 1232, 1248, 1254, and 1260).

Description of the Lower Leon Creek Sample Set

On August 6 and 7, 2002, SSD personnel collected twenty-two fish from three sites along Lower Leon Creek (map in Appendix). The SSD collected six common carp upstream of KAFB (herein after called Site 1) above the Texas State Highway 90 bridge. SSD collected four spotted gar, three largemouth bass, and four common carp from a site on KAFB property near the KAFB golf course (Site 2). SSD staff also collected two river carpsuckers and three largemouth bass from a site on private property downstream of Military Drive to the south of KAFB (Site 3).

Data Analysis

TDH toxicologists performed all statistical procedures on IBM-compatible microcomputers using SPSS software [6]. TDH generated descriptive statistics (arithmetic average concentration, standard deviation, median, range, and minimum and maximum concentrations) for each contaminant in each species at each sampling site. TDH utilized Microsoft Excel [7] spreadsheets to generate health-based assessment comparison values (HAC values; section 2.4) and to calculate hazard quotients, hazard indices, cancer risk, and allowable consumption of each fish species from the three sites along Lower Leon Creek.

[1] The literature suggests that most arsenic in fish is organic, a form of arsenic known as "fish arsenic." Humans rapidly excrete "fish arsenic" in the urine. This form of arsenic is considered virtually nontoxic [8].

[2]Nearly 100% of the mercury in upper trophic-level fish over three years of age is methylmercury [9]. Total mercury is a conservative surrogate for methylmercury concentration in fish. Because of the higher cost of methylmercury analyses, the USEPA recommends that states determine total mercury concentrations in fish and that – to be most protective of human health – states assume that all mercury in fish is methylmercury. Thus, the Texas Department of Health (TDH) analyzes fish tissues for total mercury, which includes that found as methylmercury and as inorganic mercury. In its risk characterizations, TDH compares total mercury concentrations in tissues to a comparison value derived from the ATSDR's minimal risk level for methylmercury [10]. TDH may utilize the terms "mercury" and "methylmercury" interchangeably to refer to methylmercury in fish.

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Health-based Assessment Comparison Values (HAC values)

Health-based assessment comparison values (HAC values; HAC_{nonca}; HAC_{ca}) are tissue concentrations of toxicants in fish or shellfish, exposure to which is unlikely to cause adverse health events in humans even with a lifetime of exposure. Constants employed to calculate systemic (noncancer) HAC values (HAC_{nonca}) for environmental exposures largely contain built-in margins of safety (uncertainty factors) that are devised to minimize the potential for adverse health effects. These safety factors include protection for sensitive subpopulations such as women of childbearing age, pregnant or lactating women, infants, children, the elderly, people who have chronic illnesses, or those who consume exceptionally large quantities of fish [13]. Although calculation of cancer risk does not utilize uncertainty factors, safeguards are inherent in those calculations. Notably, a slope factor is an upper bound, approximating a 95% upper confidence limit, on the increased cancer risk from lifetime exposure to an agent [14]. Consequently, adverse health effects – including cancer – are unlikely, even at concentrations that exceed a HAC value and HAC values do not represent sharp dividing lines between safe and unsafe exposures. The strict demarcation between acceptable and unacceptable exposures or risks is primarily a tool used by risk managers to assure protection of public health.

Toxicologists at the Texas Department of Health assess potential hazards of ingesting chemical contaminants in fish by comparing average contaminant concentrations to health-based assessment comparison (HAC) values (a concentration in mg contaminant per kg edible tissue - mg/kg) for systemic (non-cancerous) and carcinogenic (cancer) endpoints. In calculating HAC values, toxicologists assume that a standard adult weighs 70 kilograms and that adults consume 30 grams of fish per day (about one eight-ounce meal per week). The agency's toxicologists use the USEPA's oral reference doses (RfDs) or the Agency for Toxic Substances and Disease Registry's (ATSDR) chronic oral minimal risk levels (MRLs) to derive HAC values for systemic (noncancerous) adverse health effects (HAC_{nonca}). RfDs are estimates of daily exposures (doses; in mg/kg/day) that are not likely to cause adverse noncancerous (systemic) health effects even if exposure occurs over a lifetime [11]. MRLs and RfDs are similar in concept, so the concentrations may be identical. In some instances, however, an RfD may differ from the respective MRL because scientific judgment or interpretation can vary between regulatory agencies. Exposure concentrations that do not exceed a HAC value are unlikely to cause adverse health effects.

TDH may also assess exposures to individual contaminants by calculating a hazard quotient (HQ) – the ratio of an estimated exposure dose (in mg toxicant/kg body weight/day) to the contaminant's RfD or MRL [12]. A hazard quotient of less than 1.0 is not expected to result in adverse health effects. Although, at hazard quotients greater than 1.0, adverse health effects are possible, hazard quotients are not probability statements and are unlikely to be proportionate to risk. Thus, the mere fact that a hazard quotient exceeds 1.0 does not mean that adverse health effects would absolutely occur [11] because many other factors may affect health outcomes. These uncertainties are addressed, at least in part, by the use of "safety-" or "uncertainty factors" to calculate RfDs or MRLs.

In assessing potential increases in a theoretical lifetime cancer risk from exposure to carcinogenic chemicals, TDH uses USEPA's chemical-specific slope factors (SF) (carcinogen potency factors) [11]. To calculate HAC_{ca} values from slope factors, TDH assumes a body weight of 70 kg, a consumption rate of 30 grams per day, and an acceptable lifetime risk level (ARL) of one excess cancer in 10,000 (1×10^{-4}) persons equally exposed to the toxicant for a maximum of 30 years. Because slope factors assume lifetime exposure and because exposure to a carcinogen for thirty – rather than seventy – years implies a lower theoretical excess risk than would lifetime exposure (70 years), TDH toxicologists adjust projections of theoretical excess cancers to reflect the lower probability of cancer associated with shorter exposures.

Generally, even people who regularly eat contaminated fish consume only low concentrations of contaminants, often over an extended time. Such exposures are unlikely to cause acute toxicity but may increase the likelihood of subtle, delayed or chronic adverse health effects. Presuming that people eat a variety of contaminated fish species that may contain different contaminants in different concentrations, TDH evaluates average contaminant concentrations in each species from each site within a waterbody. If species or site differences are not present, TDH may aggregate data across species or sampling sites because such an approach is likely to reflect consumers' true exposures across time. However, the agency also may examine other exposure scenarios, including potential risks to health from ingestion of maximum observed concentrations of contaminants.

Assessment of Potential Cumulative Effects

When multiple chemicals affecting the same organ or having the same mechanism of action exist together in fish or other environmental media, scientists typically assume that the potential for adverse health effects from simultaneous exposure will be cumulative [15]. Therefore, TDH conservatively assumes people eating contaminated fish from an affected waterbody are concurrently exposed to all the observed chemicals and, further, that potential adverse health effects from such exposures are additive.

Cumulative Systemic (Noncancerous) Effects

To evaluate the importance of cumulative systemic (noncancerous) adverse health effects from consumption of contaminants with similar toxicity profiles, TDH sums the hazard quotients for all similar contaminants to generate a hazard index (HI) [15]. A HI of less than 1.0 suggests that no significant hazard is present. A hazard index in excess of 1.0 may indicate some level of hazard, but, just as a hazard quotient greater than 1.0 does not imply a definite effect, a hazard index greater than 1.0 does not imply that exposure must result in adverse health effects. Nonetheless, in the interest of public health, upon finding an HI that exceeds 1.0, the Texas Department of Health may consider some public health intervention strategy.

Cumulative Carcinogenic Effects

To estimate potential additive effects of multiple carcinogens on excess lifetime cancer risk, TDH sums the risks calculated for carcinogenic contaminants. TDH recommends that consumers

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limit consumption of fish containing multiple carcinogenic chemicals to quantities that would result in an estimated combined excess lifetime cancer risk of not more than 1 in 10,000 equally exposed persons.

Addressing Children's Unique Vulnerabilities to Exposures to Environmental Contaminants

TDH recognizes that fetuses, infants, and children may be uniquely susceptible to the effects of toxic chemicals and that any such vulnerabilities demand special attention. Windows of vulnerability (i.e., critical periods) exist during development. These critical periods are particularly evident during early gestation, but may also appear throughout pregnancy, infancy, childhood, and adolescence – indeed, at any time during development, when toxicants can permanently impair or alter the structure or function of vulnerable systems [16]. Unique childhood vulnerabilities may result from the fact that, at birth, most organs and body systems have not achieved structural or functional maturity, continuing to develop throughout childhood and adolescence. Because of these structural and functional differences, children may differ from adults in absorption, metabolism, storage, and excretion of toxicants, any one of which factors could increase the concentration of biologically effective toxicant at the target organ(s). Children's exposures to toxicants may be more extensive than adult's exposures because children consume more food and liquids in proportion to their body weight than do adults [16], a factor that also may increase the concentration of toxicant at the target. Children can ingest toxicants through breast milk – often unrecognized as an exposure pathway. They may also experience toxic effects at a lower exposure dose than adults due to differences in target organ sensitivity. Stated differently, children could respond more severely than would adults to an equivalent exposure dose [16]. Children may also be more prone to developing certain cancers from chemical exposures than are adults. If a chemical – or a class of chemicals – is shown to be more toxic to children than to adults, the RfD or MRL will be commensurately lower to reflect children's potentially greater susceptibility. Additionally, in accordance with ATSDR's *Child Health Initiative* [17] and USEPA's *National Agenda to Protect Children's Health from Environmental Threats* [16], TDH seeks to further protect children from the potential effects of toxicants by suggesting that this sensitive group consume smaller quantities of environmentally contaminated fish than adults do. Therefore, TDH routinely recommends that children who weigh 35 kg or less and/or who are eleven years of age or younger eat no more than four ounces of chemically contaminated fish per meal. TDH also recommends that consumers spread these meals out over time. For instance, if the consumption advice recommends eating no more than two meals per month, children consuming fish from the affected waterbody should consume no more than twenty-four meals per year. Ideally, children should not eat such fish more than twice per month.

RESULTS

Study Timeline

On August 9, 2002, the Seafood Safety Division (SSD) submitted twenty-two samples of fish collected from Lower Leon Creek to the TDH analytical laboratory. The TDH laboratory

returned analytical results from these samples to the SSD on November 21, 2002. The SSD Survey Branch finalized data entry and quality checks on December 16, 2002 and transferred the data to the SSD toxicologist for the present report, completed in May 2003.

Analytical Results

The TDH laboratory provided analytical results on all submitted fish tissues (twenty-two fish fillets) collected from the three sites along Lower Leon Creek (common carp, largemouth bass, river carpsuckers, spotted gar) that consisted of metals, pesticides, PCBs, volatile organic contaminants, and semivolatile organic contaminants. Although all samples contained at least one contaminant, not all fish contained all contaminants. Additionally, most contaminant concentrations approached the laboratory's reporting limits. PCBs occurred in some samples at concentrations well above laboratory reporting limits. The raw data from these analyses are available from the Seafood Safety Division, Texas Department of Health.

Metalloid Contaminants

All samples from all sites contained some level of mercury, selenium, and zinc (data not shown). Nineteen samples contained cadmium; nine contained copper (data not shown). Samples from Lower Leon Creek contained neither arsenic nor lead.

Organic Contaminants

Site 1 (Upstream of KAFB at TX Hwy 90)

Table 1 contains concentrations of chlorinated organic compounds in fish from each of the three sites. Only common carp were collected from Site 1. All carp from Site 1 contained chlordane (0.034 ± 0.02 mg/kg) and p,p'-DDE (0.026±0.02 mg/kg). One carp contained Aroclor 1260 (0.110 mg/kg). The average concentration of Aroclor 1260 in fish (carp) from upstream of KAFB was 0.035 mg/kg (Table 1; Table 2). Four carp from Site 1 contained co-eluted 3/4-methylphenol (meta- and para-cresol) at estimated concentrations below the laboratory's reporting limit (data not shown).

Site 2 (At KAFB Near Golf Course)

Concentrations of contaminants in fish from Site 2 were higher than in fish collected upstream or downstream of KAFB. Fish from Site 2 contained various combinations of chlordane, p,p'-DDD, p,p'-DDE, and/or p,p'-DDT (Table 1). One common carp from Site 2 contained heptachlor epoxide (0.0087 mg/kg) and one contained PCBs consistent with Aroclor 1248 (Table 2). Three common carp from Site 2 contained PCBs consistent with Aroclor 1260. Two spotted gar samples also contained PCBs thought to originally have been Aroclor 1248. All spotted gar contained Aroclor 1260-like PCBs (Table 2). Unusually, one largemouth bass collected at Site 2 contained Aroclor 1260 (Table 2). The four common carp from Site 2 also contained co-eluted 3/4-methylphenol at concentrations below the laboratory's reporting limit (data not shown). A

carp from Site 2 contained acetone, a common laboratory contaminant, at a level near the reporting limit (data not shown).

Site 3 (Downstream of Kelly AFB near Military Highway)

The two river carpsuckers from Site 3 contained Aroclor 1260 (0.060 ± 0.01 mg/kg), chlordane (0.038 ± 0.01 mg/kg), p,p'-DDE (0.023 ± 0.004 mg/kg), and tetrachloroethene (0.014, 0.023 mg/kg); one river carpsucker also contained p,p'-DDD (0.014 mg/kg) and trichloroethene (0.015 mg/kg). One largemouth bass contained chlordane (0.016 mg/kg), while two of three contained p,p'-DDE (0.008 ± 0.005). Fish collected downstream of KAFB did not contain measurable quantities of Aroclor 1248. One largemouth bass contained acetone at levels near the laboratory's reporting limit (data not shown).

DISCUSSION

Risk Characterization

Both inorganic and organic contaminants were present in samples from Lower Leon Creek. Metalloid contaminant concentrations were substantially below corresponding HAC values and are of no toxicologic consequence. Four carp from upstream of KAFB contained co-eluted 3/4 methylphenol (meta- and para-cresol) at levels of no concern for human health, as did all four carp from Site 2. River carpsuckers collected downstream of KAFB contained trichloroethene and tetrachloroethene at levels ranging from $1/100^{th}$ to $1/200^{th}$ of the HAC values. Although these levels do not represent a hazard to public health, it is interesting to note that trichloroethene and tetrachloroethene are among the major constituents of the shallow groundwater contamination attributed to KAFB; groundwater treated to remove pollutants is used to water the KAFB golf course or is released into Lower Leon Creek or Six-Mile Creek [18].

Chlorinated pesticides such as chlordane and p,p'-DDE did not, in any instance, exceed the HAC values established for these pollutants in fish. These contaminants were therefore – in and of themselves – of no toxicologic significance. Thus, the report does not separately address those agents. The document does discuss the potential for cumulative toxicity of PCBs and other chlorinated organic pesticides sharing a toxic mechanism or that affect the same target organ or system.

Although limited species overlap at the three sites along Lower Leon Creek complicated interpretation of the data, differences in the distribution of some toxicants were readily apparent even without inferential statistics. Inferential statistics were not performed – primarily because the study was not designed to test differences in toxicant concentrations among species or sites. Rather, TDH applied other standard risk assessment techniques to summary data to determine potential human health risks, i.e., average concentrations in fish from Lower Leon Creek were compared to concentrations determined in scientific or epidemiologic studies as unlikely to result in discernable adverse health effects over a lifetime of exposure. Concentrations of contaminants other than PCBs did not approach their respective HAC values (Table 1) and HI's for combined contaminants other than PCBs were less than 1.0 (data not shown). PCBs were present at each

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site, often at levels of potential concern for human health. Consequently, this characterization concentrates on assessing the likelihood of adverse health outcomes that could occur consequent to consumption of PCB-contaminated fish from Lower Leon Creek.

Characterizing the Likelihood of Chronic Systemic (Noncancerous) Health Effects

PCBs – of which Aroclors® are a brand name– were identified as principal contaminants in fish from Lower Leon Creek (Tables 1 and 2). In experimental animals, PCBs can cause immune suppression and other systemic health effects; the compounds may also affect development and reproduction [14]. For systemic (noncancerous) effects, TDH compares the average concentration of PCBs (TDH adds Aroclors to obtain "total" PCBs) in fish with the HAC_{nonca} for PCBs derived from USEPA's RfD for Aroclor 1254. The USEPA bases the RfD on skin and eye irritation and alterations in immune function in rhesus monkeys fed Aroclor 1254 for many weeks [14].

Site 1 (Upstream of KAFB at Texas Highway 90)

At Site 1, upstream of KAFB at the TX Hwy 90 Bridge, average concentrations of individual contaminants in fish (common carp were the only species collected from Site 1) – including PCBs – did not exceed their respective HAC_{nonca} values (Table 1, Table 2); hazard quotients for individual contaminants were not greater than 1.0. The hazard quotient for PCBs in fish from Site 1 did not exceed 1.0. The hazard index for all contaminants in common carp from Site 1 (upstream of Kelly AFB) also did not exceed 1.0 (Table 3). Thus, consumption of fish from upstream of KAFB should not pose a threat to human health.

Site 2 (At KAFB Near Golf Course)

The average concentration of PCBs in gar from Site 2 (near the KAFB golf course) exceeded the HAC_{nonca} for Aroclor 1254, as did PCBs in common carp (Table 2). The hazard quotient (HQ) for PCBs in spotted gar was 10.5; the HQ for common carp containing PCBs was 7.3 (Table 3). Hazard quotients of this order indicate that PCBs are likely to be a significant contaminant in fish harvested from Site 2 (near the KAFB golf course)– as might the unusual occurrence of Aroclor 1260 in a largemouth bass from Site 2. Concentrations in sampled fish from this site suggest that people who eat one eight-ounce meal of spotted gar per week from Site 2 could be consuming PCBs at a level 1/3 the LOAEL (lowest observed adverse effect level – the lowest concentration of a toxicant associated with adverse effects in an experimental or epidemiologic study). The composite uncertainty factor used by the USEPA to derive the RfD for Aroclor 1254 is 300. Therefore, with each meal, those who eat spotted gar from Lower Leon Creek could potentially consume 100 times the reference dose (RfD). Common carp contained comparable levels of PCBs; conclusions for common carp from Site 2 are similar to those for spotted gar from this site. One largemouth bass from Site 2 also contained PCBs – an unusual occurrence in Texas waters; the HQ was, however, less than 1.0 for PCBs in largemouth bass. Despite these mathematical predictions, adverse health effects are unlikely to ensue from occasional consumption of fish containing Aroclors at the concentrations observed in samples collected from Site 2 in Lower Leon Creek.

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Site 3 (Downstream of KAFB near Military Drive)

Two river carpsuckers collected downstream of KAFB at a site near Military Drive contained PCBs at an average concentration just slightly higher than the HAC_{nonca} for PCBs (Table 2); the hazard index for all contaminants in river carpsuckers was 1.3 (Table 3). Hazard quotients for chlordane and p,p'-DDE in river carpsuckers were less than 1.0 (data not shown). Even with PCBs present, the likelihood is low that people regularly consuming river carpsuckers from Site 3 would experience adverse health effects from exposure to environmental contaminants. Largemouth bass collected from Site 3 contained chlordane and p,p'-DDE; however, the HQ's for these contaminants were also less than 1.0 (data not shown). PCBs were not reported in largemouth bass from Site 3. Consequently, consumption of largemouth bass from downstream of KAFB should not adversely affect human health. TDH was unable to collect spotted gar, common carp, or other species from Site 3 downstream of Kelly Air Force Base.

Characterizing the Potential Risk of Cancer from Consumption of Fish from Lower Leon Creek

The USEPA classifies PCBs, DDD, DDE, DDT, and chlordane as probable human carcinogens (B2) based upon increases in the incidence of benign and cancerous tumors in animals in experimental studies [14]. Although chlorinated pesticides were present in samples from Lower Leon Creek, none were observed at concentrations that would be likely to substantially increase the risk of cancer. PCBs contribute the majority of calculated increases in the theoretical probability of cancer associated with consumption of fish from certain stretches of this waterbody. Thus, the risk characterization concentrates on increases in the theoretical risk of cancer from eating PCB-contaminated fish from Lower Leon Creek. Because calculated risks associated with consumption of PCB-contaminated fish from Lower Leon Creek varied with the collection site, the this report separately discusses findings for each site.

Site 1 (Upstream of KAFB at TX Hwy 90 Bridge)

The average concentration of PCBs in common carp from Site 1 (upstream of KAFB) did not exceed the HAC_{ca} value for PCBs (Tables 1 and 2). The calculated theoretical increase in the lifetime risk of cancer from exposure to PCBs for people who consume carp from upstream of KAFB at the TX Hwy 90 Bridge is approximately 1 in 95,000 equally-exposed persons, a figure representing no apparent increase in theoretical lifetime cancer risk (Table 4). The theoretical cancer risk does not exceed TDH guidelines for protection of human health (1 excess cancer in 10,000 equally-exposed adults).

Site 2 (At KAFB Near Golf Course)

PCBs in spotted gar from Site 2 (KAFB golf course) DID exceed the HAC_{ca} (Table 2). The excess cancer risk for those consuming PCB-containing spotted gar from around Site 2 was approximately 1 in 5800, a low probability of a discernable increase in the theoretical lifetime risk of cancer (Table 4). PCBs in common carp from Site 2 exceeded the HAC_{ca} by a factor of 1.25 (Table 2). The theoretical excess risk of cancer from consuming common carp from Site 2 was about one in 8,000 equally exposed persons (Table 4). Both risk estimates exceeded TDH

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guidelines for protection of human health (1 excess cancer in 10,000 people). Nonetheless, those who eat PCB-contaminated spotted gar or common carp from Lower Leon Creek near the golf course at KAFB (Site 2) would likely sustain only a low increase in the theoretical lifetime risk of cancer.

Consumption of largemouth bass, spotted gar, or common carp from Site 2 that do not contain PCBs would not contribute a measurable increase in the lifetime risk of cancer. For instance, consumption of common carp from Site 2 that contain average concentrations of p,p'-DDT - but that do not contain PCBs – would theoretically increase the lifetime risk of cancer by 1 in 392,950 people equally exposed to the toxicant. This is an infinitesimal increase in the theoretical lifetime cancer risk over that risk sustained by people who do not consume fish from Lower Leon Creek.

Site 3 (Downstream of KAFB near Military Highway)

Although river carpsuckers from Site 3 (downstream of KAFB) contained PCBs, the average concentration of these contaminants did not exceed the HAC_{ca} (Table 2). The risk of cancer from consuming PCBs in river carpsuckers from Site 3 would increase by 1 in 45,370 equally-exposed persons, interpreted as no apparent increase in the lifetime risk of cancer. Largemouth bass – the other species collected at Site 3 – did not contain PCBs.

Characterizing the Likelihood of Cumulative Systemic Adverse Health Effects or Cancer

Concentrations of organic contaminants other than PCBs in fish from Lower Leon Creek did not exceed HAC values for chronic systemic effects or cancer. HQ's and cancer risk estimates for each contaminant were below TDH guidelines for protection of public health. Nevertheless, several compounds in fish from Lower Leon Creek affect liver structure or function in experimental animals, cause an increase in tumors in those animals, and are classified by the USEPA as probable human carcinogens (EPA Class B2) [14]. Therefore, this investigation examined the theoretical hazards of eating fish from Leon Creek contaminated with multiple chemicals.

Site 1 (Upstream of KAFB at TX Highway 90 Bridge)

In carp (the only species collected at Site 1) from upstream of KAFB, the hazard index for chlordane, p,p'-DDD, p,p'-DDE and PCBs was less than 1.0. The theoretical excess risk of cancer from consumption of Site 1 fish contaminated with multiple chemicals was approximately1 in 95,000 equally exposed persons; qualitatively, TDH regards this risk as no apparent increase in the lifetime risk of cancer. Thus, consumption of common carp from upstream of KAFB at TX Hwy 90 that contain PCBs and other contaminants is unlikely to result in discernable systemic adverse health effects or cancer in those who eat fish from this area. If contaminants in common carp are representative of all fish near this site upstream of KAFB, consumption of other species is also unlikely to result in adverse health events.

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Site 2 (At KAFB Near Golf Course)

Fish from Site 2 generally contained more contaminants than fish from Sites 1 or Site 3 and contained the highest average contaminant concentrations observed in samples from Lower Leon Creek. Indeed, p,p'-DDT was found only in those samples collected from Site 2. The hazard index for fish from Site 2 containing PCBs, DDD, DDE, and DDT was 6.8, the majority of which was due to PCBs. If PCBs were not present, the hazard index would be well below 1.0. The hazard index for spotted gar (all of which contained PCBs) was 10.5. With minor variations, this pattern was repeated in common carp. Although largemouth bass contained PCBs and other contaminants, the hazard index did not exceed 1.0 nor was the theoretical risk of cancer increased for those who consume largemouth bass from Site 2. These results clearly indicate that PCBs are the major contributor to theoretical increases in the risk of cancer and to potential systemic adverse effects associated with consumption of fish from Lower Leon Creek near the KAFB golf course.

Site 3 (Downstream of KAFB near Military Highway)

River carpsuckers collected downstream of KAFB contained PCBs, chlordane, p,p'-DDE and p,p'-DDD. The hazard index for river carpsuckers containing multiple contaminants was 1.34. However, had river carpsuckers not contained PCBs, the hazard index would have been near zero, again indicating that PCBs were the major source of potential systemic adverse health effects. Although the hazard index for river carpsuckers was only slightly greater than 1.0, the literature suggests that some groups– including the fetus – may be more sensitive to the effects of PCBs and other contaminants than is the general population [14]. For this reason alone, a HI of 1.3 in river carpsuckers may be notable. Largemouth bass from Site 3 contained chlordane and p,p'-DDE, but did not contain PCBs and the HI for contaminants in largemouth bass was near zero (0.01). Thus, consumption of largemouth bass from Site 3 poses little risk of adverse systemic health effects. The hazard index for a combination of largemouth bass and river carpsuckers is also less than 1.0 (Table 3). Logically, then, people who eat fish from downstream of KAFB are likely to reduce their risk of noncancerous (systemic) adverse health effects by varying the species consumed and by emphasizing consumption of species such as largemouth bass that are likely to contain lower levels of many contaminants.

The theoretical increase in the probability of cancer from consumption of toxicants in river carpsuckers from Site 3 was approximately 1 in 38,000, a risk that did not exceed TDH guidelines for protection of human health (1 excess cancer in 10,000 equally-exposed adults). TDH interprets this risk estimate to represent no apparent increase in the theoretical lifetime risk of cancer. The theoretical risk of cancer from consumption of largemouth bass from Site 3 was 1 in 944,000 people, an insignificant increase in the theoretical lifetime cancer risk. The risk of cancer from eating a diet of the combined species at a ratio of three largemouth bass to two river carpsuckers was 1 in 75,616 people, representing no apparent increase in the theoretical lifetime risk of cancer (Table 4).

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Table 4*: 1.12 x 10^{-5} changed to 1.12 x 10^{-4}*

Conclusions and Public Health Implications

1. Consumption of any species of fish taken from Lower Leon Creek at or near the Kelly Air Force Base (KAFB) golf course **poses a public health hazard** for cancer and adverse systemic health outcomes, due primarily to PCBs in spotted gar and common carp.

2. Consumption of largemouth bass collected from a site in Lower Leon Creek downstream of Kelly Air Force Base **poses no apparent public health hazard.**

3. Consumption of common carp collected upstream of Kelly Air Force Base at the US Highway 90 Bridge **poses no apparent public health hazard.**

4. Consumption of a diet containing both largemouth bass and river carpsuckers from downstream of KAFB would likely reduce to an acceptable level any risk of systemic adverse health effects. Consumption of a diet consisting exclusively of river carpsuckers collected from Lower Leon Creek at a site downstream of Kelly Air Force Base *may* pose a public health hazard because adverse systemic health effects from PCBs, while unlikely, are possible, especially in sensitive subpopulations.

Recommendations for Reducing Risks from Exposure to Toxicants in Fish from Lower Leon Creek

TDH suggests that those people who seek to reduce potential risks for adverse health effects from consumption of environmentally contaminated fish eat smaller and younger fish, remove the skin and fat from the fish, and eat a variety of species from a variety of sources (waterbodies) [19]. TDH risk managers have also established certain criteria for issuing fish consumption advisories based on approaches suggested by the USEPA [13]. For instance, if calculations indicate that consumption of four or fewer meals per month (adults, eight ounces per meal; children, four ounces per meal) could result in exposures that exceed TDH health guidelines, TDH could issue advice on meal consumption for fish containing environmental contaminants. Alternatively, the Commissioner of Health can ban possession of fish from the affected waterbody under the health and safety code of the State of Texas [20]. Based on the sampling results from Lower Leon Creek, the Seafood Safety Division (SSD) and the Environmental Epidemiology and Toxicology Division (EE&TD) of the Texas Department of Health (TDH) recommend:

1. That TDH advises people not to consume any species of fish from Lower Leon Creek within the confines of Kelly Air Force Base.

2. That TDH advises people to eat a diet consisting of largemouth bass in combination with river carpsuckers from Lower Leon Creek downstream of KAFB.

3. That TDH advises the USAF of the presence of trichloroethene and tetrachloroethene in fish from a site downstream of Kelly Air Force Base.

4. That, should heavy fishing pressures be documented in that stretch of Lower Leon Creek represented by Site 3 in this risk characterization, TDH collect samples of other species to better characterize the likelihood of adverse health outcomes from consuming fish from Lower Leon Creek downstream of Kelly Air Force Base.

5. That, as resources allow, TDH continues to periodically monitor fish from Lower Leon Creek to assess the full extent of environmental contamination and to monitor trends in such contamination.

Communication of Health Risks

The Texas Department of Health (TDH) publishes fish consumption advisories and bans in a booklet available to the public through the Seafood Safety Division: (512-719-0215) [19]. TDH also posts this information on the Internet at URL: http://www.tdh.state.tx.us/bfds/ssd. Some risk characterizations for water bodies surveyed by the Texas Department of Health may also be available from the Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/HAC/PHA/region6.html). The Texas Department of Health provides the U.S. Environmental Protection Agency (URL: http://fish.rti.org), the Texas Commission on Environmental Quality (TCEQ; URL: http://www.tceq.state.tx.us), and the Texas Parks and Wildlife Department (TPWD; URL: http://www.tpwd.state.tx.us) with information on all consumption advisories and bans. Each year, the TPWD informs the fishing and hunting public of fish consumption bans in an official hunting and fishing regulations booklet [21], available at some state parks and at establishments that sell fishing licenses.

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

TABLES

Table 1. Chlorinated Organic Contaminants (mg/kg) detected in Fish from Lower Leon Creek, 2002 (Mean concentration in all fish collected from a site).

Contaminant	# Detected/ # Sampled	Average Concentration ± Std Deviation (Min-Max)	Health Assessment Comparison Value (mg/kg)	Basis for Comparison Value
Site 1 (Upstream of TX Hwy 90 Bridge)				
Chlordane	6/6	0.034 ± 0.023 (0.012-0.076)	1.17	EPA Chronic Oral RfD: 0.0005 mg/kg-day
p,p'-DDD	0/6	ND[§]	2.3	EPA Slope Factor: 0.24 per mg/kg-day
p,p'-DDE	6/6	0.026±0.022 (0.006-0.063)	1.6	EPA Slope Factor: 0.34 per mg/kg-day
p,p'-DDT	0/6	ND	1.6	EPA Slope Factor: 0.34 per mg/kg-day
Aroclor 1248	0/6	ND	0.047 mg/kg (HAC_{nonca}) 0.272 mg/kg (HAC_{ca})	EPA Chronic Oral RfD: 0.00002 mg/kg-day EPA Slope Factor for PCBs: 2.0 per mg/kg-day
Aroclor 1260	1/6	0.035±0.037 (ND-0.110)		
PCBs, Total (Aroclor 1248+Aroclor 1260)	1/6	0.035±0.037 (ND-0.110)		
Site 2 (At KAFB Near Golf Course)				
Chlordane	10/11	0.194±0.159 (ND-0.500)	1.17	EPA Chronic Oral RfD: 0.0005 mg/kg-day
p,p'-DDD	8/11	0.040±0.052 (ND-0.180)	2.3	EPA Slope Factor: 0.24 per mg/kg-day
p,p'-DDE	11/11	0.225±0.307 (0.007-1.10)	1.6	EPA Slope Factor: 0.34 per mg/kg-day
p,p'-DDT	4/11	0.016±0.032 (ND-0.100)	1.6	EPA Slope Factor: 0.34 per mg/kg-day
Aroclor 1248	3/11	0.052±0.124 (ND-0.410)	0.047 mg/kg (HAC_{nonca}) 0.272 mg/kg (HAC_{ca})	EPA Chronic Oral RfD: 0.00002 mg/kg-day EPA Slope Factor for PCBs: 2.0 per mg/kg-day
Aroclor 1260	8/11	0.252±0.218 (ND-0.690)		
PCBs, Total (Aroclor 1248+Aroclor 1260)	8/11	**0.304** ± 0.272 (nd-0.740)		
Site 3 (Downstream of KAFB near Military Drive)				
Chlordane	3/5	0.020±0.018 (ND-0.047)	1.17	EPA Chronic Oral RfD: 0.0005 mg/kg-day
p,p-DDD	1/5	0.003±0.006 (ND-0.014)	2.3	EPA Slope Factor: 0.24 per mg/kg-day
p,p-DDE	4/5	0.014±0.009 (ND-0.025)	1.6	EPA Slope Factor: 0.34 per mg/kg-day
p,p-DDT	0/5	ND	1.6	EPA Slope Factor: 0.34 per mg/kg-day
Aroclor 1248	0/5	ND	0.047 mg/kg (HAC_{nonca}) 0.272 mg/kg (HAC_{ca})	EPA Chronic Oral RfD: 0.00002 mg/kg-day EPA Slope Factor for PCBs: 2.0 per mg/kg-day
Aroclor 1260	2/5	0.036±0.022 (ND-0.066)		
PCBs, Total (Aroclor 1248+Aroclor 1260)	2/5	0.036 ± 0.022 (nd-0.066)		

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Table 4*: 1.12 x 10^{-5} changed to 1.12 x 10^{-4}*

[§]ND-not detected at a concentration greater than the laboratory reporting limit.

Table 2. Polychlorinated Biphenyls (PCBs; mg/kg) in Each Species of Fish Collected from Lower Leon Creek), 2002.

Sample site	Species	# Detected/ # Analyzed	Mean ± SD (min-max)	Health Assessment Comparison Value[†] (mg/kg)	Basis for Comparison Values
Site 1 (Upstream of Kelly AFB at TX Hwy 90)	Common carp	1/6	0.035±0.037 (ND*-0.110)	0.047 (HAC_{nonca}) 0.272 (HAC_{Ca})	EPA chronic oral reference dose (RfD): 2E-5 EPA carcinogen potency factor (slope factor): 2.0
Site 2 (Golf Course at Kelly AFB)	Common carp	3/4	**0.345** ± 0.315 (ND-0.740)		
	Largemouth bass	1/3	0.028 ± 0.014 (ND-0.044)		
	Spotted gar	4/4	**0.470** ± 0.177 (0.270-0.690)		
	Species Combined	8/11	**0.304**±0.272 (ND-0.740)		
Site 3 (Downstream of Kelly AFB near Military Drive)	Largemouth bass	0/3	ND		
	River carpsucker	2/2	**0.060** ± 0.008 (0.054,0.066)		
	Species Combined	2/5	0.036±0.022 (ND-0.066)		

** TDH calculates the average concentration of a contaminant using an algorithm for samples in which contaminants are reported as "not detected.. If a contaminant is recorded present in fewer than one-half of the samples, the concentration of that contaminant in samples recorded as "not detected" or "less than the reporting limit" is assumed to equal zero. If a contaminant is present in one-half or more of the samples, those designated "not detected" are assumed to contain a concentration equal to½ the value of the reporting limit for that contaminant.*

[†]In deriving the HAC Value, TDH assumes that a 70 kg adult will consume 30 grams of fish per day or approximately one eight-ounce meal per week. For cancer risk, TDH also assumes a 30-year exposure period. Since cancer potency factors are calculated based on a 70-year lifetime exposure, TDH adjusts the cancer risk to reflect shorter exposures.

[§] nd-less than the laboratory reporting limit of 0.04 mg/kg for Aroclors.

Table 3. Hazard indexes and allowable consumption rates (meals/month) for environmentally contaminated fish collected in 2002 from Lower Leon Creek upstream, downstream, and within the confines of Kelly Air Force Base (KAFB).

	Site 1 (Upstream of KAFB at Hwy 90)		Site 2 (At KAFB Near Golf Course)		Site 3 (Downstream of KAFB near Military Drive)	
	Hazard Index	**Meals per Month**	**Hazard Index**	**Meals per Month**	**Hazard Index**	**Meals per Month**
Common Carp	0.8	5	**8.1**	**0.5**	Not Sampled	
Spotted Gar	Not Sampled		**10.5**	**0.4**	Not Sampled	
River Carpsucker	Not Sampled		Not Sampled		**1.3**	**3**
Largemouth Bass	Not Sampled		0.63	6.4	0.01	282
All Species	0.8	5	**6.9**	**0.6**	0.8	5

Table 4. Calculated theoretical excess lifetime cancer risks and allowable consumption rates (meals per month) for environmentally contaminated fish collected in 2002 from Lower Leon Creek upstream, downstream, and within the confines of Kelly Air Force Base.

	Site 1 (Upstream of KAFB at Hwy 90)		Site 2 (At KAFB Near Golf Course)		Site 3 (Downstream of KAFB near Military Drive)	
	Excess Cancer Risk	**Meals per Month**	**Excess Cancer Risk**	**Meals per Month**	**Excess Cancer Risk**	**Meals per Month**
Common Carp	1.67×10^{-5}	24	**1.8×10^{-4}***	**2.3**	Not Sampled	
Spotted Gar	Not Sampled		**2.0×10^{-4}**	**2.0**	Not Sampled	
River Carpsucker	Not Sampled		Not Sampled		2.6×10^{-5}	15
Largemouth Bass	Not Sampled		1.28×10^{-5}	32	1.1×10^{-6}	379
All Species	1.67×10^{-5}	24	**1.12×10^{-4}**	**3.6**	1.32×10^{-5}	30

** Risk estimates that exceed TDH health guidelines are printed in* **bold-faced** *type.*

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Report prepared by:

Texas Department of Health

Jerry Ann Ward, Ph.D.
Epidemiologist II (Toxicologist)
Seafood Safety Division
Bureau of Food and Drug Safety

Michael Tennant, B.S.
Environmental Specialist III
Seafood Safety Division
Bureau of Food and Drug Safety

Susan Bush, B.S.
Survey Branch Chief
Seafood Safety Division
Bureau of Food and Drug Safety

Gary B. Heideman, B.S.
Assistant Director
Seafood Safety Division
Bureau of Food and Drug Safety

Kirk Wiles, R.S.
Director
Seafood Safety Division
Bureau of Food and Drug Safety

Richard A. Beauchamp, M.D.
Senior Medical Toxicologist
Environmental Epidemiology and Toxicology Division
Bureau of Epidemiology

Lisa Williams, M.S.
Toxicologist
Environmental Epidemiology and Toxicology Division
Bureau of Epidemiology

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7.0 Appendix: Sampling Sites along Lower Leon Creek, 2002.