Health Analysis Of Chemical Contaminants In Lower Columbia River Fish

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Washington State Department of
Health

Office of Toxic Substances

OREGON
HEALTH
DIVISION

Environmental Services and Consultation

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Acronym Listing

ATSDR	Agency for Toxic Substances and Disease Registry
Bi-State	Lower Columbia River Bi-State Water Quality Program
CNS	Central Nervous System
COC	Chemicals of Concern
CRITFC	Columbia River Inter-Tribal Fish Commission
DOH	Washington State Department of Health
EPA	U.S. Environmental Protection Agency
FDA	Food and Drug Administration
HPV	Health Protective Value
MRL	Minimal Risk Level
NOAEL	No Observed Adverse Effect Level
OHD	Oregon Health Division
PCB	Polychlorinated biphenyls
PCDD	Polychlorinated dibenzodioxins (dioxins)
PCDF	Polychlorinated dibenzofurans (furans)
PPT	Parts Per Trillion
RA	Bi-State Risk Assessment (Tetra Tech, Inc., 1996)
TCDD	Tetrachlordibenzo-p-dioxin (dioxin)
TDI	Tolerable Daily Intake
TEC	Toxic Equivalency Concentration
USGS	U.S. Geological Survey

EXECUTIVE SUMMARY

Introduction

The Lower Columbia River Bi-State Water Quality Program (Bi-State) was established in 1990 to evaluate the overall water quality of the lower Columbia River (from the Bonneville Dam to the mouth of the Columbia River). Initial Bi-State surveys found chemicals in several fish species exceeding risk-based screening levels. A human health risk assessment was conducted by the Bi-State program, and results showed contaminants in some fish at high enough levels to potentially affect human health. Though limitations in the Bi-State data did not permit definitive conclusions, the Washington State Department of Health (DOH) and the Oregon Health Division (OHD) prepared this health analysis to complement the Bi-State risk assessment and to help fish consumers better understand the health implications of the Bi-State data.

In general, a health analysis goes beyond the process of risk assessment by looking more deeply at the complex parameters of what constitutes and contributes to good health and incorporates these variables into the evaluation of exposures to contaminants in fish relative to fish consumers' overall health. The goal is to accurately characterize and communicate potential health risks from fish contaminants while providing information relative to health benefits of eating fish. In the case of the Bi-State data, this health analysis also provides some perspective on the limitations of the available data so that people are aware of the uncertainties associated with using these data for deriving health conclusions.

Methods

Columbia River Bi-State fish tissue samples collected in surveys conducted in 1991, 1993, and 1994-1995 were used as the basis for this health analysis. These surveys included whole body and fillet samples of carp, largescale sucker, and peamouth, and fillet samples of salmon, steelhead, and sturgeon.

The health analysis focuses on the five primary contaminants of potential concern identified from more than 100 contaminants analyzed for in Bi-State samples. These include two metals (arsenic and mercury) and three chlorinated organics (PCBs, dioxins/furans, and DDT/DDE). For the health analysis, mean concentrations of the primary contaminants of concern were compared with health protective screening values.

Because of the high degree of uncertainty associated with estimates of excess cancer risk, the health analysis focuses on potential noncancer effects from exposure to fish contaminants. The health agencies believe that the noncancer effects of the contaminants in Columbia River fish are more clearly defined than cancer risk estimates and are therefore more appropriate for balancing potential adverse effects against known benefits of fish consumption.

Limitations

Though the Bi-State surveys provide the most extensive collection of fish tissue data to date for the river, many of these data had limited usability for the health analysis. Limitations of the data include: small numbers of samples for some fish (e.g. carp, salmon and steelhead); a high percentage of nondetected data for some chemicals; noncomparability between sampling surveys, so that data could not be combined across surveys; lack of data for some recreationally important fish species such as walleye; and a predominance of whole body samples for some fish. The health agencies considered these data limitations and other factors (e.g. health benefits of eating fish, individual health sensitivities) to develop qualitative conclusions regarding the potential health significance of the chemicals found in lower Columbia River fish.

Results

The health analysis indicates that arsenic and mercury levels in sampled fish are considerably below a level for which health impacts would be expected. However, levels of PCBs, dioxins/furans, and DDT/DDE in some fish samples (especially carp, peamouth, and largescale sucker) exceed health protective criteria.

Conclusions

Data limitations and uncertainties do not support the issuance of a quantitative fish advisory (i.e. an allowable fish consumption rate) at this time. However, the health agencies have determined that more general recommendations are warranted, in order to protect the health of fish consumers.

PCBs, dioxins/furans, and DDT/DDE have in common the potential to adversely affect human development. These contaminants are found in the highest concentrations in whole body samples of bottom-feeding fish (carp, peamouth, largescale sucker); thus, frequent consumers of bottom-feeding fish, especially whole body preparations of these fish, have the highest potential risk.

Recommendations

Because (1) the endpoint of concern is developmental effects; (2) the contaminants of concern tend to accumulate in fatty tissues of exposed persons over time; and (3) these contaminants can be transferred to the developing fetus or to infants via breastmilk, recommendations regarding fish consumption are particularly directed toward pregnant and nursing women and women of reproductive age. Children are also included in these recommendations because they are still developing and may be more exposed, on a body weight basis, due to their size.

Women of reproductive age, pregnant and nursing women, and young children:

Limit consumption of peamouth, carp, and largescale sucker. These consumers can further reduce their exposure by avoiding whole body preparations of these fish (such as those which include the skin and/or internal organs) and by following certain preparation and cooking guidelines. These guidelines are: (1) trim fatty portions from the fish, including the skin, before cooking; and (2) cook fish so the fat is allowed to drip away (such as broiling). This recommendation is based on levels of PCBs, dioxins/furans, and DDT/DDE that have been found in these fish. Since these chemicals accumulate in the fatty tissues of fish (i.e. they are lipophilic), following the recommended preparation and cooking methods will reduce intake of these chemicals.

People who frequently eat carp, peamouth, and largescale sucker:

Reduce consumption of these fish, avoiding whole body preparations. Follow the preparation and cooking guidelines provided in order to reduce the intake of lipophilic compounds.

People who frequently eat salmon, steelhead, and sturgeon, or who occasionally eat carp, largescale sucker, and peamouth:

Follow the preparation and cooking methods provided above to reduce the intake of lipophilic compounds. These consumers can further reduce their exposure by avoiding whole body preparations of these fish.

The health departments will update these recommendations, as needed, pending additional useable information on the levels of chemicals in lower Columbia River fish and/or when toxicity information becomes available that would suggest the need for a new evaluation.

1.0 INTRODUCTION

The Lower Columbia River Bi-State Water Quality Program (Bi-State) was formed in 1990 by the Oregon and Washington State Legislatures. The Bi-State program was established to study the water quality in the lower Columbia River, identify water quality problems, determine whether beneficial uses of the river are impaired, and develop solutions to identified problems [Bi-State Risk Assessment (RA), Tetra Tech, Inc., 1996]. The Bi-State study area consists of the 146 mile stretch of river from the Bonneville Dam to the mouth of the river at the Pacific Ocean.

The lower Columbia River human health risk assessment study was conducted because initial Bi-State surveys found chemicals in several fish species sampled throughout the study area that exceeded risk-based screening values (Tetra Tech, Inc., 1994a). The purpose of the risk assessment was to evaluate potential risks to human health from eating lower Columbia River fish (RA, 1996). The results of the risk assessment indicated that some of the chemicals detected in fish were at high enough levels to potentially impact human health. These results prompted the Washington State Department of Health (DOH) and the Oregon Health Division (OHD) to look more closely at the Bi-State data and prepare a health analysis. The purpose of this analysis is to further evaluate, in terms of overall health impact, the chemicals identified by the risk assessment as potentially of concern and to help fish consumers better understand the health implications of the contaminants found in fish.

A health analysis goes beyond the process of risk assessment by looking more deeply at the complex parameters of what constitutes good health and incorporates these variables into the evaluation of exposures to contaminants in fish relative to fish consumers' overall health. For some people, the health benefits from eating fish may outweigh small increased risks from exposure to fish contaminants. Eating fish has been shown to have important beneficial effects on the heart and circulatory system, and provides a protein source low in fat [U.S. Environmental Protection Agency (EPA), 1995a; Great Lakes Sport Fish Advisory Task Force, 1993]. In this analysis, the health agencies considered health sensitivities and other factors (e.g. benefits of eating fish, differences in fish consumption patterns) that may be important when determining the possible effects to individuals from eating lower Columbia River fish. Certain individuals, such as children, pregnant and nursing women, older people, and those in poor health, may be more sensitive to certain contaminants. These and other factors were considered by the health agencies in developing conclusions about the public health significance of the chemicals found in lower Columbia River fish.

The goal of this health analysis is to identify and communicate health risks to people who eat lower Columbia River fish while providing information regarding the health benefits of eating fish. Fish is an excellent source of protein and vitamins. In addition to meeting basic nutritional needs, eating a diet high in fish may also provide other health benefits (EPA, 1995a). These health benefits include decreased risk of cardiovascular disease, reduction in blood pressure, and reduced risk of some cancers. It is possible that restricting fish consumption could negatively impact the health of individuals who benefit from eating fish. Some other protein sources may not be healthful alternatives to fish for some people, especially those with existing health conditions, such as diabetes and cardiovascular disease, for which diets low in cholesterol and saturated fats are recommended.

By carefully evaluating the Bi-State data and the assumptions used in the risk assessment, the health departments have attempted to better define health risks from consumption of lower Columbia River fish. It is hoped that this effort will provide fish consumers with the information they need to make choices within the framework of their individual health status and fish consumption patterns.

This analysis provides information to help consumers of lower Columbia River fish make personal decisions about whether or not they should modify their current fish consumption habits. Additionally, the health analysis includes recommendations fish consumers can take to reduce their exposure to fish contaminants, such as preparing and cooking fish in a certain way or eating less of or avoiding particular species.

2.0 METHODS AND LIMITATIONS

2.1 Bi-State Risk Assessment Data

During 1991 through 1995, the Bi-State program collected and analyzed fish tissue samples for chemical contamination from the 146 mile stretch of river from the Bonneville Dam to the mouth of the Columbia River (RA, 1996). Fish sampling surveys were conducted in 1991, 1993, and 1994-1995.

The 1991 and 1993 surveys were reconnaissance surveys, which were designed to provide a preliminary assessment of water quality and to guide future studies (RA, page 1-2). The 1991 survey consisted of collecting whole body composite fish samples of carp, largescale sucker, peamouth (a total of 37 samples) and 18 individual fillet samples of sturgeon. In the 1993 survey, a total of 18 whole body composite fish samples of carp and largescale sucker were collected. Whole body fish samples were collected as part of the 1991 and 1993 surveys in order to satisfy one of the survey's primary objectives, which was to characterize fish tissue contaminants to which fish-eating wildlife could be exposed (RA, page ES-2).

In contrast, the purpose of the 1994-1995 survey was to collect data specifically for use in a human health risk assessment. The 1994-1995 sampling protocol called for the collection of composite fillet samples, with skin on (except for sturgeon, which were analyzed without skin). Samples were collected for steelhead and chinook and coho salmon (3 samples each); carp (1 sample); largescale sucker (9 samples); and individual sturgeon fillets (12 samples) (Health Analysis Appendix, Tables 1-3).

2.2 Application of Toxicity and Exposure Information

The impact of a fish contaminant on health depends on how toxic the contaminant is and the degree of exposure. Exposure is determined by the chemical concentration in the fish, the amount and frequency of fish consumption, and the exposure duration. The Bi-State risk assessment used what are called "high-end" or "worst case" estimates for several exposure parameters, including consumption of fish for 350 or 365 days per year for 30 or 70 years. Such conservative assumptions are commonly used in risk assessment when site-specific information is lacking. While this approach is useful for providing worst-case estimates of risk (e.g. for establishing environmental cleanup levels or for developing regulations for prevention of contamination), it is less useful for determining risks to the general population of fish consumers. Also, as is noted in the uncertainty section of the risk assessment (RA, page 6-1), the risk assessment calculations do not take into consideration the likelihood that lipophilic contaminant levels to which fish consumers will actually be exposed will likely be less than that detected in raw fish samples because of cooking and/or preparation losses or because not all parts of the fish may be consumed.

Uncertainties exist regarding the chemical toxicity values (reference doses and slope factors developed by EPA) used in risk assessment. Reference doses and slope factors are generally derived from animal studies or from studies involving humans with unusually high occupational exposures. High dose human and animal data are then extrapolated to estimate the health effects that might occur in humans at much lower environmental levels. The health departments generally rely on EPA's toxicity values for screening purposes only, because of the conservative assumptions used to derive these values for regulatory purposes. The health departments prefer to rely on chemical-specific toxicity analysis for evaluating public health risks.

The reference dose, the toxicity value used for evaluating noncancer health effects, is the maximum daily exposure level to a chemical which is unlikely to impact human health. Reference doses are determined by dividing by "safety factors" the highest dose level that does not produce an adverse effect in the experimental animal (the NOAEL or No Observed Adverse Effect Level). A safety factor of 10 is almost always applied to account for different sensitivities within the human population. When animal data are used, another factor of 10 is used to account for differences between animals and humans. Other safety factors may also be applied. The reference dose is compared to an estimated daily exposure (equal to contaminant concentration times consumption rate) to determine if noncancer health effects could occur.

Reference doses rely on an underlying assumption that noncancer health effects will occur only after a certain chemical dose (called a threshold) is achieved. EPA assumes that cancer-causing chemicals, on the other hand, lack thresholds for producing health effects; that is, some cancer risk exists at any exposure. Toxicity values for cancer-causing chemicals are derived by using mathematical models to predict risks at low doses from high dose experimental data. Such high doses are used in animal cancer tests because cancer is a relatively rare outcome (i.e. 1 in 10,000) from low level exposures; in order to induce tumors in a small dose group (typically 50 animals), the amount of chemical administered must be relatively large. Cancer models produce what are called "upper-bound" estimates of risk which may or may not give an accurate risk prediction; in some cases the actual cancer risk may, according to EPA, sometimes be as low as zero (EPA, 1987).

Because of the high degree of uncertainty associated with estimates of cancer risk, this health analysis focuses on potential noncancer effects (primarily developmental effects) from exposure to fish contaminants. Cancer risk estimates are included for comparative purposes. The health agencies believe that the noncancer effects of the contaminants in Columbia River fish are more clearly defined than cancer risk estimates and are therefore more appropriate for balancing potential adverse effects against known benefits of fish consumption. In this respect, the health analysis differs substantially from the Bi-State risk assessment.

2.3 Data Usability for the Health Analysis

Although the Bi-State surveys represent the most extensive collection of water quality data to date for the lower Columbia River, these data had to be used carefully by the Oregon and Washington departments of health for making definitive conclusions about actual health risks. For example, it is unlikely that the Bi-State fish data are representative of actual contamination in all fish over the entire river area (146 miles). Additionally, the Bi-State samples are predominantly from bottom-feeding fish (such as carp, sucker, and sturgeon) which tend to have higher chemical concentrations; non-bottom feeding fish such as bass or salmon are either underrepresented or not represented at all in Bi-State samples.

The data include only limited information on fish species known to be caught frequently in the river, such as salmon, walleye, and bass, and only limited data on the levels of contaminants in the fillet portions of the fish. Whole fish samples, which make up the bulk of the Bi-State data, tend to have higher concentrations of contaminants. Fish may ingest some contaminants but not absorb them, resulting in higher concentrations in the gut. Other contaminants may be concentrated in certain organs (such as the liver) or may be stored in bone. For these and other reasons, chemical concentrations in whole body fish samples generally exceed fillet concentrations. Though whole body data are obviously important for assessing risks to consumers of whole fish, most recreational fishers eat primarily fish fillets and do not consume fish organs or bones.

This section describes in more detail the limitations of the Bi-State fish tissue data and how these data were used in this health analysis. Where appropriate, explanations of why data were used differently from the Bi-State risk assessment are also provided.

2.3.1 Chemicals Evaluated in the Health Analysis

The health analysis focuses on those few chemicals of concern (COC) identified in the Bi-State risk assessment as having the greatest potential health risk. Though this approach simplifies the evaluation, it is also protective, as the COC represent almost all of the identified risk (RA, Tables

5-5 and 5-6). The chemicals evaluated in the health analysis are: polychlorinated dibenzodioxins and polychlorinated dibenzofurans (dioxins/furans); polychlorinated biphenyls (PCBs); DDT/DDE; arsenic; and mercury. As in the risk assessment, the health analysis uses the arithmetic mean fish concentrations of these chemicals to estimate average exposure concentrations.

Though the fish contaminants are evaluated individually relative to their potential toxicity, the health agencies are aware that chemicals in combination may have additive effects. This is a particularly important consideration in this analysis, as most of the COC have been shown to affect development. The issue of combined chemical exposure is addressed in the section Recommendations to Consumers of lower Columbia River Fish (Section 4.2).

2.3.2 Nondetected Data

A significant problem with using some of the Bi-State data for the health analysis is that there were many samples in which chemicals were not detected (i.e. the chemical concentrations were below laboratory detection limits). The standard approach for handling nondetected chemicals in risk assessment is to assume a value equal to half the detection limit. This is done because the chemical might be present but the analysis simply cannot detect it. A value of half the detection limit is often used as it is a compromise between using zero, which may be too low, and using the detection limit, which may be too high. This approach is a standard procedure for risk assessment. As in the Bi-State risk assessment, the health analysis uses half the detection limit in calculating average fish tissue concentrations.

Some chemicals, such as PCBs, were detected in almost every fish sample analyzed. Therefore, the average fish concentration calculated for PCBs is based on actual detected data and gives a good approximation of the average concentrations of PCBs across all the fish species sampled. However, a high percentage of the fish fillet analyses found that dioxins and furans were below detection limits (Health Analysis Appendix, Table 3). The average concentrations of dioxins and furans are, in many cases, based largely on nondetected data (using half detection limit). It is assumed that these chemicals might be present at levels below the detection limit.

2.3.3 Fish Species and Tissue Types

As noted above, another difficulty in using some of the risk assessment results for making broad recommendations about health is that the results are based on chemicals found in some fish species and parts of fish that many people may not eat. For example, the purpose of the 1991 and 1993 surveys was to get a preliminary assessment of all the chemicals present in the lower Columbia River; these surveys were not designed to specifically address human exposures (RA, page 1-2). Because of this, many fish species that are known to be recreationally important, such as salmon, walleye and bass, were not sampled in these surveys.

The 1991 and 1993 surveys also focused primarily on whole body fish samples rather than edible fillets. PCBs, dioxins/furans, and DDT accumulate in the fatty portions of the fish, such as the skin and internal organs (especially the liver). Therefore, concentrations of these chemicals are higher in whole body fish samples, compared to the leaner fillet. Though whole body data are useful for characterizing exposures to people who eat the entire fish, they overestimate exposures to people who generally consume only the fillet.

In contrast to samples collected in 1991 and 1993, the 1994-1995 sampling was designed specifically to collect data relevant to human exposures (RA, page ES-1). This sampling was planned to provide skin-on fish fillet data from recreationally important fish species, including salmon, steelhead, walleye and bass (Bi-State Sampling and QA/QC Plan, Tetra Tech, Inc., 1994b). Unfortunately, walleye and bass could not be collected due to the timing of sampling (RA, page 2-7) and thus chemical exposure estimates relative to these important resident recreational species cannot be made. The salmon, steelhead, carp and largescale sucker data do provide a reasonable range of chemical concentrations, which is assumed to bracket walleye and bass concentrations. Carp and largescale sucker were used to estimate worst case exposures for game species since they are expected to accumulate higher concentrations of organics than water column species such as trout or salmon, due to their habitat, feeding behavior, and higher fat content (RA, pages 1-4 and 1-5).

2.3.4 Sample Size

Another limitation of the Bi-State data is that there are relatively few samples of some fish. For example, one composite fillet sample of carp and three composite fillet samples each of steelhead, chinook and coho were collected and used to represent fish fillet contaminant concentrations in these species for the entire 146 mile river segment. Although these samples indicate that chemicals are accumulating in the fish to some degree, they provide only very limited information on the range of chemical concentrations in fish throughout the lower part of the river. Additional fish sampling, spanning the length of the lower Columbia River, would help determine if fish contaminant levels are similar throughout the river or if there are areas where contamination is higher or lower.

2.3.5 Comparability Across Surveys

Another limitation of the fish tissue data is that there are many differences among the three sampling surveys which preclude the pooling (combining) of data across surveys for most of the species sampled. Pooling data across surveys has the advantage of increasing the numbers of samples for estimating contaminant exposures from eating fish. Having a greater number of samples to average gives a stronger measure of the central tendency of the data.

There are several reasons why the data from the three surveys cannot be pooled. For example, the carp and largescale sucker collected for fillet analysis in the 1994-1995 survey appear to be larger (as determined by fish lengths and weights reported in RA, Appendix A) than fish caught for whole body analysis in the 1991 and 1993 surveys. Within a given species, body size is a fairly reliable indicator of fish age. Older fish tend to have greater accumulations of persistent contaminants (PCBs, DDT, dioxins) as a result of their increased time of exposure. Since the Bi-State 1991 and 1993 whole body and 1994-1995 fillet samples are not from similar-sized fish, the 1994-1995 fillet data cannot be used to quantitatively estimate concentrations in fillets of fish from the 1991 and 1993 surveys. Therefore, only 1994-1995 samples can be used to address exposures to contaminants from fillets of these fish. For carp especially, this provides only very limited fillet data (one carp fillet composite).

In addition to differences in sizes of some fish species across surveys, there are also differences in laboratory detection limits. For example, detection limits achieved for the 1994-1995 survey were substantially lower for several contaminants (e.g. PCBs and pesticides) than for earlier surveys (RA, Table 2-2).

Sampling locations across surveys also differ for some fish. For example, the carp samples collected for the 1991 surveys were collected from the upper part of the study area (river mile 80 - 140), while the 1993 carp samples were collected from the extreme ends of the study area (approximately river mile 10 and 140) (RA, Figures 2-1 and 2-2).

There are also differences in the concentrations of some contaminants across surveys which are difficult to interpret. For example, one PCB Aroclor, 1248, that was detected in the 1994-1995 carp, largescale sucker and sturgeon fillets was not detected in any of the whole body or fillet samples of these same fish in the 1991 and 1993 surveys (Health Analysis Appendix, Table 1 and 2). Another example is the DDT and DDE data for largescale sucker. Concentrations of total DDT and DDE were six times higher in 1993 whole body largescale sucker samples (mean of 111 ug/kg) compared to 1991 whole body largescale sucker samples (mean of 17.5 ug/kg) (Health Analysis Appendix, Table 1 and 2), although the size range of fish from the two surveys was similar (RA, Appendix A) and the fish were collected from similar locations along the river (RA, Figures 2-1 and 2-2). Analytical differences in the laboratories used for the different surveys may have contributed to this variability (RA 2-11), but there is no way to determine to what extent this is the case. It is difficult, therefore, to determine which concentrations should be used in estimating exposures from eating these fish.

3.0 HEALTH ANALYSIS FOR INDIVIDUAL FISH CONTAMINANTS

The following section summarizes the main toxic effects of the chemicals of concern and evaluates the levels of the contaminants detected in Bi-State fish samples. Due to the limited nature of the Bi-State fish tissue data and time constraints, existing health based comparison values are used to evaluate the Bi-State data, when available. Ideally, a health analysis requires a more complete environmental dataset with which to make quantitative recommendations about allowable fish consumption amounts. In addition, a thorough review of the toxicity literature pertaining to the contaminants of concern is typically performed before developing advice to fish consumers. In lieu of a more complete health analysis, the following analysis was developed in order to satisfy the immediate needs of the Bi-State and to help consumers of lower Columbia River fish understand the health implications of the Bi-State data. It is not thought that the Bi-State data are strong enough to justify a more in depth toxicity review and health analysis at this time.

3.1 PCBs

Polychlorinated biphenyls (PCBs) are a group of 209 individual chemical compounds, called congeners, that were used extensively in electrical capacitors and transformers because of their insulating properties. Although the manufacture of PCBs was discontinued in the United States in 1977, many older electrical transformers and capacitors still contain PCBs. PCBs are very stable compounds and therefore can remain in the environment for many years. PCBs are ubiquitous in the environment and have been detected widely in fish and sediments.

Commercially, PCBs were sold as mixtures of individual congeners. In the United States, most of these mixtures were sold under the trade name Aroclor. Aroclors are named by the percent chlorine in the total mixture and not by the percent composition of individual congeners. For example, in Aroclor 1254, the 12 indicates that the parent molecule is a biphenyl (2 phenyl groups containing 12 carbons) and the 54 indicates percent chlorine content by weight (54%). Bi-State fish tissue samples were analyzed for Aroclor mixtures and not individual congeners. Because of the variable composition of Aroclors, individual congeners cannot be directly estimated from the Aroclor data.

Once PCBs are absorbed into the body they are primarily stored in fatty tissues including liver, fat, breast milk, and skin. As they are not quickly excreted, PCBs tend to accumulate in the body. Health effects observed in workers exposed to high levels of PCBs for many years include chloracne (a severe acne-like skin condition), liver damage, and possibly some types of cancer. A large number of people in Japan who accidentally ate PCB-contaminated rice oil exhibited some of the same health effects seen in workers exposed to PCBs. Although it was initially thought that health effects observed in these people were due solely to PCBs, it was subsequently determined that contaminants of the PCBs, chlorinated dibenzodioxins and dibenzofurans, were the main causative agents (ATSDR, 1993a). PCBs have been associated with reproductive, developmental, and immunological changes; liver effects, including liver cancer, have also been observed in laboratory animals. Developmental effects have been observed in babies and children exposed to lower levels of PCBs in breast milk.

Recent studies of the toxicity of PCBs have focused on individual PCB congeners. Some PCB congeners bind to the same cellular receptor as dioxins and appear to produce dioxin-like effects. Though more and more information is being obtained on the different toxicities of individual PCB congeners, this information could not be used to evaluate the Bi-State data for the health analysis since individual congeners were not measured in fish samples. Analysis of individual PCB congeners was proposed in the planning stages of the Bi-State risk assessment; however, this analysis was not conducted due to its high cost and because Aroclor analysis was expected to provide sufficient information on PCB levels in fish. The health departments recommend that future Columbia River fish sampling include individual PCB congener analysis so that health risks can be more precisely evaluated.

Both cancer and noncancer effects of PCBs were evaluated in the Bi-State risk assessment. Cancer risk projections are based on potency estimates extrapolated from doses that produced liver tumors in PCB-exposed rodents. Immune system and developmental effects observed in primate studies are the basis of EPA's reference doses (0.07 and 0.02 mg/kg/day, respectively), which were used to evaluate noncancer effects in the Bi-State risk assessment.

For the health analysis, DOH and OHD utilized a recent assessment of potential health effects from eating PCB-contaminated fish in the Great Lakes. The Great Lakes Sport Fish Advisory Task Force (GLSFATF), which includes representatives from Ohio, Illinois, Indiana, Pennsylvania, New York, Wisconsin, Minnesota and Michigan health departments and other agencies from these states, recently prepared a methodology for assessing the hazards of PCB-contaminated fish and has derived a proposed Health Protective Value, or HPV (GLSFATF, 1993). This approach to assessing health risks was developed to address the widespread problem of PCB fish contamination in the Great Lakes. In 1990, the concentration of total PCBs in whole lake trout ranged from approximately 500 ug/kg in Lake Superior to approximately 3000 ug/kg in Lake Michigan (EPA, 1993).

The Great Lakes HPV was used by the health departments to evaluate the Bi-State data for several reasons: (1) it was specifically derived for assessing exposure to PCBs from fish consumption; (2) it specifically addresses a sensitive toxic endpoint (a developmental endpoint); and (3) it does not rely on individual PCB congener data. The Great Lakes HPV, expressed as a daily dose, is 0.05 ug total PCBs/kg body weight/day. The HPV is intended to encompass reproductive and developmental endpoints as well as an allowable cancer risk (at a 1 in 10,000 excess cancer risk level), and is similar to EPA's two Aroclor reference doses (0.07 mg/kg/day for Aroclor 1016, and 0.02 mg/kg/day for Aroclor 1254). The HPV is equivalent to 50 ug/kg total PCBs in fish fillet at a fish consumption rate of 140 gm/day (approximately 5 oz/day) or 220 ug/kg total PCBs in fish fillet at the lower fish consumption rate of 32 gm/day (approximately 8 oz/week) (see Health Analysis Appendix, Table 4 for comparative values). The HPV incorporates an estimated 50% reduction in PCB contaminants due to cleaning and cooking.

At least one Aroclor was detected in every Bi-State fish tissue sample. In the 1994-1995 samples, total PCBs (summation of all Aroclors) in fillets were detected at levels ranging from 3.05 to 188.5 ug/kg mean concentration. Mean concentrations of total PCBs in whole body samples from all surveys ranged from 78.5 ug/kg to 269.3 ug/kg, with varying percentages of nondetected data.

Bi-State samples of steelhead, chinook, and coho fillets are below the HPV of 50 ug/kg total PCBs by about a factor of 10. It thus appears, based on these limited numbers of samples at least, that the levels of PCBs found in these fish will not adversely impact fish consumers' health. The levels of PCBs detected in sturgeon and largescale sucker fillets are close to the HPV, which suggests that people eating these types of fish frequently should consider taking some precautions to reduce exposure to PCBs. These precautions include trimming skin and fat before cooking, avoiding eating whole fish (which tend to have higher concentrations than fillets), and cooking fish so the fat is allowed to drip away.

The potential impact on health from eating carp and peamouth is less clear because of the small number of samples of these fish and because it is not known if consumers generally eat these fish whole or if they eat only the fillets. Since the levels of PCBs found in whole body carp and peamouth samples are about three times the HPV, it is recommended that people eating whole body carp and peamouth consider eating less of these fish or eating only the fillets and cooking them in the manner described above.

Since the sizes of carp caught across the three sampling surveys are not comparable (the 1994-1995 carp composite consisted of larger fish than the 1991 and 1993 samples; see RA, Appendix A), generalizations about levels of PCBs in fillet versus whole body portions cannot be made from the Bi-State data. It is expected that PCB concentrations in carp fillets from fish of comparable size to the 1991 and 1993 samples would be lower than the levels found in the whole body samples; however, this cannot be directly concluded from the data. The one composite sample of carp fillets suggests that larger carp (of about 3000 grams or about 6 and a half pounds) may contain levels of PCBs above the HPV. It is impossible, however, to make generalizations about the levels of PCBs in all carp fillets based on this one composite sample.

3.2 DDT/DDE

DDT was used extensively as an insecticide in the United States until its sale and application to crops were banned here in the early 1970s. Stockpiled DDT stores can still be found in agricultural areas and in homes in the United States and some DDT deposition through rainfall is occurring locally from its use worldwide. DDT breaks down very slowly and can persist in the environment for many years. DDT and its degradation products (primarily DDE and DDD) are highly lipophilic and accumulate in the fatty tissues of exposed fish and people. Once absorbed, DDT and DDE remain stored in the body for decades.

The effects of DDT, DDE, and DDD have been extensively studied in laboratory animals and to a lesser extent in people exposed to high levels either occupationally or in controlled human studies. Health effects observed in animal studies include effects on the blood, liver, nervous system, kidneys, and on development and reproduction. DDT has been shown to cause liver tumors in rodents, which has prompted EPA to classify DDT as a possible human carcinogen. Health effects associated with exposure to DDT have been much less pronounced in human studies, which have mainly evaluated liver effects.

DDT or DDE was detected in at least one sample of every fish species sampled for the Bi-State study. Mean concentrations of DDT and DDE combined (DDT/DDE) detected in 1994-1995 fish fillet samples range from 3.84 ug/kg in coho composites to 131 ug/kg in the single carp composite (Table 3). Concentrations of DDT/DDE in whole body fish samples range from 17.5 ug/kg in largescale sucker to 158 ug/kg in peamouth (Tables 1 and 2). DDT and DDE were detected in nearly all 1994-1995 fillet samples and 1993 whole body samples. However, DDT and DDE were only detected in about half of the 1991 whole body samples (percent nondetect of individual samples ranged from 100% to 24%, see Health Analysis Appendix, Table 1). Differences in detection limits from sampling year to year may have accounted for some of the differences in the percent detection.

The Bi-State risk assessment used standard EPA toxicity values to evaluate the potential cancer and noncancer effects of DDT, DDE, and DDD in lower Columbia River fish. The highest excess cancer risk calculated in the Bi-State risk assessment for a DDT compound was approximately 1×10^{-4} for DDE in 1994-1995 carp fillets and 1991 whole body peamouth at a fish consumption rate of 176 gm/day over 70 years (RA, Table 5-3). The highest hazard quotient (estimated exposure divided by the reference dose) calculated in the Bi-State risk assessment for a DDT compound was 7×10^{-1} (0.7) for p,p'-DDE in 1991 whole body peamouth (RA, Table D-15). Hazard quotients less than one indicate that the estimated exposure is less than the reference dose, and therefore unlikely to impact health.

An alternative approach, developed in 1992 by DOH (Marien and Laflamme, 1995), was used to evaluate the Bi-State data for this health analysis. This approach was considered more appropriate for the health analysis because it relies on more recent information regarding the developmental effects of DDT than that used for EPA's reference dose.

DOH developed a DDT action level based on fish collected from the Yakima River by the U.S. Geological Survey (USGS) in 1989-1991 (Marien and Laflamme, 1995). The USGS found relatively high levels of DDT and its breakdown products in bottom-feeding fish in the Yakima River, Washington (100 - 4370 ug/kg whole fish; 60 - 1010 ug/kg fillet). Based on these data, DOH developed an action level for DDT/DDE in fish and subsequently issued a health advisory for the Yakima River recommending that people restrict their consumption of bottom-feeding fish and take other precautions to reduce exposures.

DOH's action level for DDT in fish was based on a tolerable daily intake (TDI) determined from recent developmental toxicity studies in rodents. The Agency for Toxic Substances and Disease Registry (ATSDR) also based their allowable daily intake for noncancer effects, called a minimal risk level (MRL), on the same dataset used by DOH (ATSDR, 1994a). DOH's TDI is based on neurodevelopmental effects observed following exposure to DDT soon after birth. Due to the timing of exposures and effects, DOH's advisory was aimed at protecting infants exposed to DDT through breast milk. Of special concern were women of childbearing age consuming large amounts of bottom-feeding fish (largescale sucker and mountain whitefish) as this exposure could increase women's DDT body burden.

The TDI developed for the Yakima River advisory is 0.005 mg of total DDT and DDE/kg body weight/day. This is equivalent to a fillet concentration of 61 ug/kg, derived specifically for people eating a large amount of fish (200 gm/day fish consumption rate or 7 oz/day). People eating a smaller amount of fish would not likely be affected by DDT and DDE at the action level of 61 ug/kg (Health Analysis Appendix, Table 4 for comparative values). DDD was not included in DOH's TDI since it is readily excreted in the urine and is unlikely to be found in breast milk (and would therefore not be expected to contribute to a nursing infant's exposure).

In the 1994-1995 Bi-State data, the single carp fillet sample had a DDT/DDE concentration of 131 ug/kg, approximately twice the action level; other 1994-1995 fillet samples did not exceed the action level. In the whole body samples, the 1991 peamouth sample was more than twice the action level (158 ug/kg, based on 60% nondetected data). Concentrations of DDT/DDE in 1993 whole body samples of carp and largescale sucker also exceeded the action level (85.3 and 111 ug/kg, respectively); other whole body samples were less than the action level.

As with other highly lipophilic substances, DDT and DDE partition into the body fat of fish. Whole body fat content is higher than that of the cleaned fillet. Whole body concentrations of lipophilic compounds have been shown to exceed concentrations in fillets [Great Lakes Sport Fish Advisory Task Force, 1993; Niimi and Oliver, 1989 (PCBs); Marien and Laflamme, 1995 (DDT/DDE)]. For largescale sucker and mountain whitefish collected from the Yakima River, analysis of whole body and fillets from the same group of fish showed that levels of DDT/DDE in fillets were approximately one half to one fifth of the whole body concentrations (Marien and Laflamme, 1995).

The relationship between whole body and fillet concentrations cannot be evaluated in the Bi-State carp data since the carp sizes were not similar in the whole body and fillet samples. The seven individual carp which made up the single composite sample in the 1994-1995 survey were larger than carp collected for the 1991 and 1993 whole body analyses (RA, Appendix A). However, it is expected that concentrations of DDT/DDE in carp and peamouth fillets of comparably-sized fish to those collected in 1991 and 1993 would be lower than whole body concentrations.

Because of these data limitations, it is difficult to draw general conclusions about the levels of DDT/DDE in variously-sized carp throughout the river. In addition, it is not known if people are frequently eating carp of a particular size or how they are preparing the carp. However, the data do suggest that people who are frequently eating heavier carp (>3000 grams or 6 and a half pounds) or who are eating smaller-sized whole carp should consider taking precautions to reduce their exposures to DDT/DDE. People, especially women of reproductive age, and pregnant and nursing women, who frequently eat carp should avoid eating the whole fish and instead eat only the fillet, trim skin and fat before cooking, and cook fish so that fat is allowed to drip away (e.g. by broiling).

In addition to carp, concentrations of DDT/DDE in whole body largescale sucker and peamouth exceeded DOH's action level developed for fillets. Concentrations of DDT/DDE in largescale sucker fillets were below DOH's action level and do not appear to be a concern. As it is expected that the levels of DDT/DDE in peamouth fillets would be lower than levels found in whole body samples, the primary concern is with people who may be eating these fish whole. Again, the actual health impact from eating peamouth is unclear because of the small number of samples and because it not known if people are eating a large amount of these fish. Additionally, information is not available about what parts of the fish people are eating (fillet or whole). Based on these limited number of samples, however, it is recommended that people who do frequently eat these types of fish, especially nursing and pregnant women and women of childbearing age, follow the precautions outlined above for fish preparation and cooking.

3.3 Dioxins/Furans

2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD, dioxin) is the most toxic of a group of tricyclic, chlorinated hydrocarbons that are produced as unwanted byproducts of certain industrial and combustion processes. These chemicals, termed polychlorinated dibenzodioxins (PCDD) and polychlorinated dibenzofurans (PCDF), have been detected in all media, including air, soil, water, and sediment. They are also found commonly in foods, particularly in fish, meat and dairy products. Though there are 210 possible PCDD/PCDF congeners, only those having chlorine substitutions in the 2,3,7,8 positions (7 of the PCDD congeners and 10 of the PCDF congeners) are currently believed to have dioxin-like toxicity.

PCDD/PCDF are released to the environment through combustion and through various industrial processes, including chlorine bleaching of pulp and paper, wood treatment, and the manufacture of chlorinated pesticides and other chemicals. Though all sources of Columbia River PCDD/PCDF have not yet been clearly identified, studies have shown that pulp and paper mills have historically been primary contributors. Effluent from other industrial processes utilizing chlorine and combustion emissions are also likely sources. Redistribution of PCDD/PCDF released in the past, through sediment resuspension and aerial deposition, is probably also significant.

Foods, particularly meat, eggs, dairy products, and fish, have been identified as the primary source of human exposure to PCDD/PCDF (Schecter et al., 1994). The high lipophilicity and low water solubility of PCDD/PCDF strongly favors their bioconcentration/biomagnification in fish, and consumption of large quantities of contaminated fish can be an important source of exposure for certain populations (Schell et al., 1993). Several studies have shown elevated blood levels of PCDD/PCDF in high consumers of contaminated fish (Svensson et al., 1991).

The human toxicity of PCDD/PCDF is not clearly understood and is currently the subject of a massive reassessment by EPA (EPA, 1994a, 1994b). New studies on the effects of TCDD on developmental and other sensitive endpoints have been conducted by various laboratories and are being evaluated by EPA in its dioxin reassessment. Also, included as part of this reassessment are exposures from other sources in an attempt to determine total body burden of TCDD. EPA considers PCDD/PCDF "probable" human carcinogens, which means that there is sufficient evidence of carcinogenicity from animal studies but insufficient evidence from human studies. The potential noncancer effects of PCDD/PCDF in humans are numerous, including chloracne, liver damage, suppression of the immune system, developmental and reproductive effects, and disruption of regulatory hormones. Though there is considerable controversy regarding what level of dioxin exposure constitutes a health risk, it has been hypothesized that some effects could be occurring in certain individuals at or near background exposure levels (Birnbaum, 1994).

Though 2,3,7,8-TCDD is by far the most studied of this group of chemicals, dioxins and furans always occur in combination. An interim method for quantifying health risks associated with PCDD/PCDF mixtures has been adopted by EPA (EPA, 1994a). In this system, PCDD and PCDF congeners having chlorine substitutions in the 2,3,7,8 positions have been assigned toxic equivalency factors (TEFs) from 0.001 to 0.5 based on their potency relative to 2,3,7,8-TCDD, which is assigned a value of 1.0. Congener concentrations are multiplied by their respective TEFs to yield TCDD-equivalent concentrations. Summing these individual concentrations yields the total toxic equivalency concentration, or TEC. TECs (also called TEQs) are the values that are generally used in dioxin/furan risk assessment.

The Bi-State study found mean fish TECs ranging from 1.7 to 8.1 parts per trillion (ppt) in whole body fish (Tables 1 and 2) and 0.23 to 3.0 ppt in fillets (Table 3). Except for carp, the 1994-1995 fillet samples (assuming a value equal to half the detection limit for nondetects) were close to EPA's screening level of 0.7 ppt (based on a 10^{-5} or 1 in 100,000 excess cancer risk; EPA 1995b). The single carp fillet sample from 1994-1995 had a TEC of 3.0, which is four times EPA's screening level. The 1991 and 1993 whole body data were generally consistent with the 1994-1995 results, assuming that whole body PCDD/PCDF are approximately twice fillet values. The highest TEC (8.1 ppt) was found in 1991 whole body peamouth. The 1991 sturgeon fillets had a TEC of 2.31.

Because of the high degree of uncertainty regarding the cancer and noncancer effects of PCDDs/PCDFs in humans, the potential health significance of the levels found in the Bi-State study is not clear. Eighteen states currently have fish advisories for dioxins/furans. PCDD/PCDF screening levels (fish concentrations which could trigger the issuance of an advisory) for these states range from 0.7 ppt (EPA's screening level) to 25 ppt (Food and Drug Administration's (FDA) action level). ATSDR has reviewed the current literature on the developmental effects of TCDD and has proposed a MRL of 0.7 pg/kg/day (Pohl et al., 1995). For a 54 gm/day fish consumption rate (approximately 1 pound per week), this level corresponds to a fish concentration of 0.9 ppt TCDD. ATSDR has indicated that the MRL will not be finalized until EPA's dioxin reassessment is complete. Neither DOH nor OHD has a current screening value for TCDD.

Though potential noncancer effects of fish PCDDs/PCDFs were not specifically addressed in the main body of the Bi-State risk assessment, the uncertainty analysis does include calculations of PCDD/PCDF hazard quotients, using ATSDR's proposed MRL of 0.7 pg/kg/day (RA, page 6-6; Table 6-2). Calculated results indicated that PCDD/PCDF could be a major contributor to the developmental hazard index.

Excess cancer risk estimates from exposure to fish PCDD/PCDF in the Bi-State study range up to a maximum of 3 in 1,000, when conservative exposure assumptions (a diet consisting exclusively of whole body peamouth and a consumption rate of 176 gm/day, 365 days/year for 70 years) are used. Assuming a 54 gm/day consumption rate (approximately 1 pound per week), PCDD/PCDF estimated excess cancer risks for most fish are in the range of 1 in 10,000 to 1 in 100,000.

In 1991, DOH calculated TEC from TCDD/TCDF levels analyzed in sportfish (walleye, lake whitefish, rainbow trout, mountain whitefish, Kokanee) caught from Lake Roosevelt (DOH, 1991). Advice to limit consumption to no more than 20 meals/month (100 gm/meal or 4 oz/meal for infants, 200 gm/meal or 8 oz/meal for adults) was based on developmental endpoints. DOH is awaiting the release of EPA's final reassessment before revisiting the Lake Roosevelt advisory. Because multiple pollutants with a similar toxic endpoint (developmental) are being evaluated in this health analysis, advice to fish consumers differs from that given for Lake Roosevelt. However, DOH may choose to amend the Lake Roosevelt advice pending the release of EPA's reassessment of TCDD.

The uncertainties associated with dioxin/furan toxicity, Bi-State data limitations, and uncertainties relative to Columbia River fish consumption patterns make definitive conclusions regarding potential health risks from Columbia River fish PCDD/PCDF difficult. However, risks to the average recreational fisher, who catches and consumes a variety of fish and eats only the fillet, are probably not significant. High fish consumers, those who regularly consume fish known to have higher PCDD/PCDF levels (carp, largescale sucker, and peamouth), and those who regularly consume whole body fish may be at increased risk.

The fish dioxin/furan levels found in the Bi-State study are not high compared to national background levels. However, the uncertainty regarding a safe level of intake and the recognized toxic potency of these substances, especially the recognition that developmental effects are one of the most sensitive endpoints, justifies caution. For this reason, OHD and DOH recommend that pregnant and nursing women and women of reproductive age limit their consumption of those fish identified as having elevated levels of dioxins and furans (peamouth, largescale sucker, and carp). Others who eat fish from the river should include these fish species in their diet only occasionally. Consumers of Columbia River fish can further limit their exposure by avoiding whole body fish, removing skin and fat, and cooking fish so the fat is allowed to drip away.

3.4 Arsenic

Arsenic is a naturally-occurring element which can exist in several different forms. Inorganic arsenic can be found in many kinds of rocks and is the most toxic form of arsenic. The arsenic found in some fish and shellfish is mostly an organic form (i.e. combined with a carbon compound) which is much less toxic than the inorganic forms. Since arsenic is an element, it does not break down; however, it can change from one form to another in the environment. Arsenic compounds have been used widely as pesticides and as wood preservatives. In some areas, arsenic can occur in unusually high natural levels in rock, which can lead to high levels in soil and water.

Ingested arsenic has been identified as a health hazard that can affect many systems of the body. Health effects associated with arsenic can vary depending on the dose and length of exposure. Although acute high-dose effects may be important in some situations, an exposure to high doses of arsenic from eating lower Columbia River fish is extremely unlikely because the concentrations found in fish tissues are too low. Therefore, only health effects caused by chronic low-dose exposure will be considered for this health assessment.

There is strong evidence that arsenic ingestion can cause cancer in humans. Arsenic is classified as a known human carcinogen by EPA and the World Health Organization. Cancers of the lung, skin, liver, bladder, and kidney have been associated with long-term ingestion of small quantities of arsenic. Arsenic also causes many health effects unrelated to cancer such as increased blood pressure, changes in skin, paresthesia, muscle weakness, and Blackfoot disease (dry gangrene).

Studies which have examined groups of people who drank arsenic-contaminated water for extended periods of time provide the best information for estimating chronic arsenic toxicity in people. Numerous groups of people drinking water contaminated predominantly with inorganic arsenic have been studied in many parts of the world, including Taiwan, China, Mongolia, India, Chile, Mexico, Argentina and Canada. Among these studies there was consistency in the lowest chronic dose that produced health effects. The estimated doses of inorganic arsenic that produced health effects in these studies ranged from less than 10 ug/kg/day up to 30 ug/kg/day. EPA bases its evaluation of arsenic toxicity on studies which have looked at a population in Taiwan exposed to various amounts of arsenic in drinking water.

Most of the arsenic in fish is in a relatively non-toxic organic form called arsenobetain ("fish arsenic"). Inorganic arsenic, which is considerably more toxic, makes up a small amount of total arsenic in fish and is most relevant for assessing health impacts from eating fish. In the Bi-State data, total arsenic was measured in fish for all three sampling surveys. Inorganic arsenic concentrations were estimated from total arsenic concentrations (1991 and 1993 surveys; RA, page 3-8) or were measured directly (1994-1995 survey). Estimates of cancer risks and noncancer hazards in the Bi-State risk assessment are based on inorganic arsenic.

The highest concentrations of inorganic arsenic, either measured directly or estimated from total arsenic, were detected in sturgeon fillets from the 1994-1995 survey. In the Bi-State risk assessment, arsenic is the only metal which contributes to total cancer risk. It accounts for only a small portion of risk from each of the fish species (up to 18.9 %; RA, Table 5-5). The highest total excess cancer risk calculated for arsenic for any one fish species is 1.7×10^{-4} (approximately equal to a dose of 0.1 ug/kg/day) in 1995 sturgeon using a 70 year exposure duration and a 176 gm/day (6 oz/day) fish consumption rate (RA, Table 5-3). Total excess cancer risk estimates for arsenic for all other species were lower. Arsenic contributed only a small percentage to the total noncancer hazard in the risk assessment (maximum 13.8 %; RA, Table 5-6).

Considering the relatively low excess cancer risks and noncancer hazards calculated for arsenic, DOH and OHD believe that the levels of arsenic which have been found in lower Columbia River fish will not impact the health of people eating fish from this area. One reason for this conclusion is that the risks calculated in the Bi-State risk assessment are relatively low. Additionally, the health departments compared the exposures calculated in the risk assessment to the levels of arsenic exposures in studies of people who were exposed to arsenic through drinking water. The highest exposure estimated in the Bi-State risk assessment, 0.1 ug/kg/day from eating 176 grams of fish/day, is 100 times lower than the lowest exposures associated with health effects in populations exposed to arsenic through drinking water. This dose level is also below ATSDR's MRL of 0.0003 mg/kg/day for inorganic arsenic (ATSDR, 1993b).

Because arsenic is distributed throughout fish tissues, there are no cooking or trimming methods that can reduce arsenic intake. The only effective means of reducing arsenic exposure is to limit fish consumption either by reducing fish intake or by specifically avoiding eating large amounts (>176 gm/day or 6 oz/day) of sturgeon.

3.5 Mercury

Mercury is a naturally-occurring element that is present at low levels in rocks, soil, sediments, air, and water. In addition to natural sources, mercury is released to the environment from mining, runoff from sanitary landfills, municipal refuse incineration, certain fungicides, and direct discharge of industrial wastes. In lakes and rivers, elemental mercury is converted to methylmercury by chemical reactions and by the action of bacteria.

Fish absorb methylmercury from aquatic organisms they eat and from water as it passes over their gills. Once absorbed, methylmercury binds tightly to fish tissues. With continued exposure, methylmercury levels can build up in fish. Thus, older fish have higher concentrations of methylmercury than younger fish. As fish absorb methylmercury from food, predatory fish (such as walleye) which prey on other smaller contaminated fish, accumulate the mercury and become more contaminated. Fish at the highest levels of the food chain generally have the highest concentrations of methylmercury in their tissues.

The toxicity of methylmercury to humans depends on the amount taken in and the duration of exposure. Though humans eliminate methylmercury, the process is slow. When the amount of mercury taken into the body exceeds the amount eliminated, mercury levels can build up in humans. Thus, exposure to relatively low levels over an extended period is potentially harmful.

The central nervous system (CNS) is a major target organ for methylmercury. Studies have shown that exposure of adult humans to high levels of methylmercury can result in tremor, spastic paralysis, incoordination, changes in speech and hearing, and other sense perception changes. Methylmercury can cross the placenta and can be transferred to breast milk. The CNS of developing fetuses and young children is particularly susceptible to the toxic effects of methylmercury. Other potentially susceptible groups include the elderly, people with impaired organ function, and people with existing health conditions or poor nutritional status.

Methylmercury levels in fish analyzed for the Bi-State study had mean levels ranging from 0.044 mg/kg to 0.219 mg/kg. The highest mean levels found for each year's sampling were 0.219 mg/kg (1991 whole body carp), 0.168 mg/kg (1993 whole body largescale sucker) and 0.153 mg/kg (1995 largescale sucker fillet). The Bi-State risk assessment identified methylmercury as the primary contributor to the hazard index for the CNS endpoint (RA, Table 5-6).

Though Washington State currently has no fish advisories for mercury, fish mercury advisories are in effect for several Oregon lakes. Consistent with EPA guidance (EPA, 1995b), the Oregon Health Division bases these advisories on a minimum average fish methylmercury screening level of 0.6 ppm (using a 6.5 gm/day fish consumption rate or approximately 6 oz/month) (see Health Analysis Appendix, Table 4 for comparative values). This screening level is designed to protect the most sensitive populations, including young children and developing fetuses. As the data indicate that methylmercury levels in Columbia River fish are substantially lower than 0.6 mg/kg, a mercury-based advisory for these fish does not appear to be warranted.

At this time, DOH and OHD believe that the methylmercury levels in Columbia River fish are too low to pose a health concern to the general population. (DOH is currently reviewing mercury toxicity information, which may result in future changes to the conclusions presented here.) However, the 0.6 ppm screening level used is based on a low fish consumption rate (6.5 gm/day or 6 oz/month) and does not take into account other dietary sources of methylmercury such as canned tuna. (FDA allows up to 1 ppm in canned tuna.) Sensitive populations such as young children, pregnant women, and women of reproductive age who may want to decrease their intake of methylmercury should not eat large amounts of Columbia River fish. As methylmercury is distributed throughout fish tissues, there are no cooking or trimming methods that can reduce mercury intake; the only effective means of reducing exposure to fish methylmercury is to reduce fish consumption.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Health Analysis Summary and Conclusions

The Bi-State risk assessment identified five primary contaminants of potential concern in Lower Columbia River fish. These included two metals (arsenic and mercury) and three chlorinated organics (PCBs, dioxins/furans, and DDT and its derivatives). DOH and OHD have evaluated the Bi-State data, within the context of overall public health, to determine if the levels of contaminants found pose a risk to consumers of lower Columbia River fish and whether fish consumption should be restricted (i.e. a fish advisory should be issued).

Analysis of the Bi-State data indicates that arsenic and mercury concentrations in the fish sampled are below a level of concern. The highest arsenic exposure level estimated in the risk assessment, 0.1 ug/kg/day for a fish consumption rate of 176 gm/day (6 oz/day), is 100 times lower than the lowest arsenic exposures associated with health effects in studies of populations exposed through drinking water; this dose is also less than ATSDR's MRL of 0.3 ug/kg/day. The highest mean mercury concentration detected was 0.219 mg/kg in 1991 whole body carp, which is below the 0.6 mg/kg screening level [based on a 6.5 gm/day (6 oz/month) fish consumption rate] used by OHD and EPA.

The potential health significance of the chlorinated organics is less clear. PCBs, DDT/DDE, and dioxins/furans were detected in all fish species sampled, and, in several cases, health protective criteria were exceeded. For PCBs, the Great Lakes HPV of 50 ug/kg (based on a 140 gm/day or 5 oz/day consumption rate of fish fillet) was exceeded in all of the whole body samples analyzed and in the sturgeon and carp fillets. Steelhead, chinook, and coho fillet sample concentrations were below the HPV by a factor of 10. DDT/DDE levels above DOH's Tolerable Daily Intake action level of 61 ug/kg (based on a 200 gm/day or 7 oz/day consumption rate of fish fillet) were found in carp fillet and in peamouth and 1993 carp and largescale sucker whole body samples; levels in sturgeon, steelhead, chinook, and coho fillet and in 1991 whole body carp and largescale sucker samples were below the action level. Though a generally accepted health protective criterion has not been established for dioxins/furans, EPA's screening value of 0.7 ppt and a calculated value of 0.9 ppt based on ATSDR's proposed MRL were exceeded in carp and sturgeon fillet and in whole body samples of carp, largescale sucker, and peamouth. These results indicate that frequent consumers of these types of lower Columbia River fish may be at increased risk from exposure to these contaminants.

DOH and OHD are concerned when contaminants are detected in fish. However, as previously indicated, Bi-State data limitations relative to fish species sampled and sample numbers, large numbers of sample nondetects, limited information regarding consumption rates and preparation practices of lower Columbia River target species, and other uncertainties preclude making definitive conclusions regarding the significance of these contaminants in terms of overall fish consumer health.

One of the difficulties faced by the health departments in interpreting the Bi-State sampling results is the lack of information regarding fish consumption practices in the lower Columbia River. Though the data indicate that people who frequently eat certain kinds of fish from the river (bottom-feeding fish like carp or long-lived fish like sturgeon) over an extended period of time may be at risk, populations fitting this consumption pattern have not been identified. Native American tribal members frequently eat salmon caught upstream of the Bi-State study area; however, Bi-State tribal representatives have indicated that Columbia River Inter-Tribal Fish Commission (CRITFC) tribes do not generally fish in the lower river (personal communication Tom Backman, CRITFC representative to the Bi-State, October 1995).

The aim of this health analysis has been to carefully evaluate and interpret the available data and to provide as much information as possible about actual health risks from eating lower Columbia River fish. The ultimate goal of this process is to educate fish consumers, so they can make informed decisions about what actions they should take, if any, to reduce their exposures. The health analysis has shown that chemical contaminants in some lower Columbia River fish are high enough to represent a potential health risk to frequent consumers of these fish. Though the many data limitations and uncertainties do not support the issuance of a quantitative fish advisory (an allowable daily intake or specifications regarding the size and number of fish meals), in order to be protective, the health departments are issuing a more general advisory. The health departments are recommending that frequent consumers of lower Columbia River fish, particularly sensitive populations (women of reproductive age, pregnant and nursing women, and children) take certain precautions. These precautions are outlined in the following section.

It should be stressed that the health analysis of lower Columbia River fish contaminants is a dynamic process and may be revised as additional information regarding fish contaminant levels and/or regional fish consumption patterns becomes available.

4.2 Recommendations to Consumers of Lower Columbia River Fish

Bi-State results indicate that concentrations of the chemicals of primary concern (PCBs, DDT/DDE, dioxins/furans) are highest in bottom-feeding fish species (carp, peamouth, and largescale sucker) and in whole body fish; thus, frequent consumers of bottom-feeding fish, especially whole body preparations of these fish, have the highest potential risk. Groups of special concern are women of reproductive age, pregnant and nursing women, and children who may frequently consume these fish, as these consumers have been identified as particularly sensitive to the developmental effects of the contaminants found in the fish.

Though the data are limited, the health departments believe that, because (1) the chemicals of most concern found in fish can accumulate in the body over time; (2) several of these chemicals are associated with effects on development; (3) evidence is accumulating that exposure to low levels of these chemicals may be associated with endocrine alterations; and (4) uncertainties exist regarding the toxicity of some of these chemicals at low level exposure, the following protective recommendations are justified. These recommendations may change as more data become available.

Women of reproductive age, pregnant and nursing women, and young children:

Limit consumption of peamouth, carp, and largescale sucker. These consumers can further reduce their exposure by avoiding whole body preparations of these fish (such as those which include the skin and/or internal organs) and by following certain preparation and cooking guidelines. These guidelines are: (1) trim fatty portions from the fish, including the skin, before cooking; and (2) cook fish so the fat is allowed to drip away (such as broiling). This recommendation is based on levels of PCBs, dioxins/furans, and DDT that have been found in these fish. Since these chemicals accumulate in the fatty tissues of fish (i.e. they are lipophilic), following the recommended preparation and cooking methods will reduce intake of these chemicals.

People who frequently eat carp, peamouth, and largescale sucker:

Reduce consumption of these fish, avoiding whole body preparations. Follow the preparation and cooking guidelines provided in order to reduce the intake of lipophilic compounds.

People who frequently eat salmon, steelhead, and sturgeon, or who occasionally eat carp, largescale sucker, and peamouth:

Follow the preparation and cooking methods provided above to reduce the intake of lipophilic compounds. These consumers can further reduce their exposure by avoiding whole body preparations of these fish.

The health departments will update these recommendations, as needed, pending additional useable information on the levels of chemicals in lower Columbia River fish and/or when toxicity information becomes available that would suggest the need for a new evaluation.

4.3 Recommendations to Bi-State

Although the health analysis utilized the Bi-State data in a manner somewhat differently from the Bi-State risk assessment, the health departments are strongly supportive of risk assessment for use in regulatory programs. For several reasons, risk-based environmental regulations use a very protective approach. Risk-based water or air quality standards are designed to protect an entire population or ecosystem, including organisms more vulnerable than humans. Some contaminants can build up in the environment or in biological systems over time. Thus, relatively low levels of contaminants may indicate a potential future problem. While a health analysis tends to focus on immediate recognizable health threats, risk-based environmental regulations characteristically are based on a long range view that encompasses pollution prevention as well as pollution reduction. Additionally, risk-based environmental regulations incorporate protective assumptions to try to account for multiple pollution sources and exposure routes. Without this protective and broad approach, environmental regulations could not adequately protect and maintain a healthy environment for people and wildlife.

The health departments offer the following recommendations to the Bi-State program.

1. Sample and analyze chemical concentrations in walleye and bass, as originally planned in the Human Health Risk Assessment Sampling Plan (Tetra Tech, Inc., 1994b). These data will provide information on the levels of contaminants in these recreationally important fish species. Additional sampling and analysis of fish fillets of carp, peamouth, salmon, and steelhead is also recommended.

2. Continue to monitor levels of contaminants in the fish species sampled by the Bi-State program. These data will allow tracking of changing fish contaminant levels over time.

3. Collect additional samples to identify geographical hot-spot areas of contamination. This will enable the health departments to identify specific areas of highest potential exposure.

4. Gather information regarding lower Columbia River fish consumption patterns, particularly for populations which may be consuming fish species identified as most heavily contaminated. As noted in this analysis, the health departments lack information regarding persons who may frequently eat carp, largescale sucker, peamouth, and sturgeon. As the Bi-State Steering Committee represents a broad range of lower Columbia River interests, it is expected that they will be the first line of contact for people having concerns or information about populations consuming these types of fish frequently.

The health departments hope that the release of this health analysis highlights the need for further information about the levels of contaminants in lower Columbia River fish and people who frequently consume these fish. This kind of information will help the health departments make more definitive conclusions in the future about the safety of eating lower Columbia River fish. The health departments are available to consult with the Bi-State program and others regarding future sampling and analysis plans to insure useable data collection for health analysis purposes.

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Health Analysis

Appendix

Table 1. Chemical Concentrations in 1991 whole body and fillet samples.

Chemical	Mean Concentration (ug/kg, ng/kg for TEC) (%ND)			
	Carp (whole body) 9 composites of 5 individual fish (5 composites for dioxins)	L. Sucker (whole body) 18 composites of 5 individual fish (12 composites for dioxins)	Peamouth (whole body) 10 composites of 5 individual fish (7 composites for dioxins)	Sturgeon (fillet)[1] 18 individual fish samples (7 for dioxins)
dioxin TEC ½ DL*	4.31 (13%)	2.7 (0%)	8.1 (16%)	2.31 (85%)
Aroclor 1242	ND	ND	37.7(80%)	ND
Aroclor 1254	110 (44%)	127 (6%)	ND	64.1 (78%)
Aroclor 1260	49.6 (56%)	30.8 (94%)	190(0%)	ND
Total PCBs	159.6	157.8	190	64.1
DDT (op+pp)	6.5 (67%)	6.6 (pp) (24%)	ND	7.7 (75%)
DDE (op+pp)	42.8 (45%)	10.9 (op) (47%)	158 (60%)	21 (56%)
DDT + DDE	49.3	17.5	158	28.7
As (inorg.)	ND	ND	ND	44.3[a] (59%)
Hg (total)	219 (0%)	80.7 (0%)	121 (0%)	166 (12%)

Data summarized from Table B-7 of Bi-State Risk Assessment (Tetra Tech, Inc., 1996).
Mean calculated from detected data + ½ detection limit for non-detects.
*DL = detection limit
[a] Inorganic arsenic based on conversion factor from total arsenic measurement (RA, page 3-8).
[1] Sturgeon fillet samples were analyzed without skin.
ND = nondetect

Table 2. Chemical Concentrations 1993 whole body samples.

Chemical	Mean Concentrations (ug/kg, ng/kg for TEC) (%ND)	
	Carp 2 composites of 4 individual fish	L. Sucker 16 composites of mostly 5 individual fish
dioxin TEC		
½ DL*	1.7 (56%)	1.8 (60%)
Aroclor 1254	50.5 (0%)	230 (0%)
Aroclor 1260	28 (50%)	39.3 (50%)
Total PCBs	78.5	269.3
DDT (pp)	3.8 (0%)	14 (0%)
DDE (pp)	81.5 (0%)	97 (0%)
DDT + DDE	85.3	111.0
As (inorg.)	ND	2.49[a] (94%)
Hg (total)	72.8 (50%)	168 (0%)

Data summarized from Table B-8 in Bi-State Risk Assessment (Tetra Tech, Inc., 1996).
*DL = detection limit
Mean calculated from detected data + ½ detection limit for non-detects.
[a] Inorganic arsenic based on conversion factor from total arsenic measurement (RA, page 3-8).
ND = nondetect

Table 3. Chemical Concentrations in 1994/1995 fillets samples.

Chemical	Mean Concentration in Fillet[1] (ug/kg, ng/kg for TEC) (%ND)					
	Carp 1 composite of 7 individual fish	Steelhead 3 composites of 8 individual fish	Chinook 3 composites of 8 individual fish	Coho 3 composites of 8 individual fish	L. Sucker 9 composites of 8 individual fish	Sturgeon 12 individual fish samples
dioxin TEC						
full DL*	4.4 (60%)	0.43 (86%)	1.02 (65%)	1.01 (59%)	1.46 (79%)	0.91 (84%)
½ DL	3.0	0.23	0.8	0.8	0.85	0.85
zero DL	1.6	0.04	0.6	0.6	0.35	0.39
Aroclor 1248	50.5 (0%)	ND	ND	ND	6.4 (56%)	11.7 (42%)
Aroclor 1260	138 (0%)	5.06 (0%)	9.97 (0%)	3.05 (0%)	33.5 (0%)	46.4 (0%)
Total PCBs	188.5	5.06	9.97	3.05	39.9	58.1
DDT	ND	3.17 (0%)	1.47 (0%)	.813 (0%)	1.7 (33%)	1.07 (0%)
DDE	131 (0%)	2.26 (0%)	8.52 (0%)	3.03 (0%)	2.32 (0%)	41.9 (0%)
DDT+DDE	131	5.43	9.99	3.84	4.02	42.97
As (inorg.)	1.0 (0%)	6.5 (33%)	12.8 (33%)	2.67 (67%)	12.5 (11%)	39.1 (0%)
Hg (total)	145 (0%)	63.7 (0%)	99.7 (0%)	44.0 (0%)	153 (0%)	63.3 (0%)

TEC = Toxic Equivalency Concentration of PCDDs and PCDFs combined.
Data summarized from Table B-10 in Bi-State Risk Assessment (Tetra Tech, Inc., 1996).
Mean concentrations calculated from detected data + ½ detection limit for non-detects.
TEC based on full and zero DL from Appendix A, draft Bi-State Risk Assessment (Tetra Tech, Inc., 1995)
*DL = detection limit
[1] Fillets samples were analyzed with skin on, except for sturgeon, which was analyzed without skin.
ND = nondetect

Table 4. Summary of Health Comparison Values Used in Health Analysis.

Chemical	Comparison Value (fish concentration, when applicable). See text for further description of Comparison Values.	Parameters used in derivation of Comparison Value	Health Endpoint	Comparison Value (fish concentration) standardized for 54 gm/day (≈ 2 oz/day) fish consumption rate.	Reference
TCDD	0.9 ppt TCDD	54 gm/day fish consumption rate; proposed MRL of 0.7 pg/kg/day	developmental	0.9 ppt (TCDD)	ATSDR, proposed MRL (Pohl et al., 1995)
PCBs	50 ug/kg (total PCBs) in fillet	140 gm/day fish consumption rate; 50% reduction due to cleaning/cooking	developmental/ reproductive	130 ug/kg	Great Lakes Sport Fish Advisory Task Force, 1993
DDT + DDE	61 ug/kg (DDT+DDE) in fillet	200 gm/day fish consumption rate	developmental	226 ug/kg	Marien and Laflamme, 1995
Arsenic (inorganic)	0.0003 mg/kg/day	a NOAEL of 0.0008 mg/kg/day (human study) Uncertainty factors of 3 to account for sensitive individuals	dermal effects		ATSDR, 1993b
Mercury	600 ug/kg in fillet	6.5 gm/day fish consumption rate (Uses prior EPA RfD of $6\text{x}10^{-5}$ mg/kg/day)	developmental	72 ug/kg (120 up/kg using updated EPA RfD of $1\text{x}10^{-4}$ mg/kg/day)	EPA, 1995b