Health Consultation

Lower Duwamish Waterway Site: Updated Fish Consumption Advisory and Evaluation of Marine Tissue Collected from the Lower Duwamish Waterway in August and September 2004.
Seattle, Washington

September 7, 2005

Prepared by

The Washington State Department of Health
Under a Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

DOH Pub. No. 333-103

Foreword

The Washington State Department of Health (DOH) has prepared this health consultation in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the U.S. Department of Health and Human Services and is the principal federal public health agency responsible for health issues related to hazardous waste. This health consultation was prepared in accordance with methodologies and guidelines developed by ATSDR.

The purpose of this health consultation is to identify and prevent harmful human health effects resulting from exposure to hazardous substances in the environment. Health consultations focus on specific health issues so DOH can respond to requests from concerned residents or agencies for health information on hazardous substances. DOH evaluates sampling data collected from a hazardous waste site, determines whether exposures have occurred or could occur, reports any potential harmful effects, and recommends actions to protect public health. The findings in this report are relevant to conditions at the site during the time of this health consultation, and should not necessarily be relied on if site conditions or land use changes in the future.

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Glossary

Acute	Occurring over a short time [compare with **chronic**].
Agency for Toxic Substances and Disease Registry (ATSDR)	The principal federal public health agency involved with hazardous waste issues, responsible for preventing or reducing the harmful effects of exposure to hazardous substances on human health and quality of life. ATSDR is part of the U.S. Department of Health and Human Services.
Carcinogen	Any substance that causes cancer.
Chronic	Occurring over a long time (more than 1 year) [compare with **acute**].
Contaminant	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.
Dose (for chemicals that are not radioactive)	The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.
Environmental Protection Agency (EPA)	United States Environmental Protection Agency.
Exposure	Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [**acute exposure**], of intermediate duration, or long-term [**chronic exposure**].
Ingestion	The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].
Ingestion rate	The amount of an environmental medium that could be ingested typically on a daily basis. Units for IR are usually liter/day for water, and mg/day for soil.
Oral Reference Dose (RfD)	An amount of chemical ingested into the body (i.e., dose) below which health effects are not expected. RfDs are published by EPA.

Parts per billion (ppb)/Parts per million (ppm)	Units commonly used to express low concentrations of contaminants. For example, 1 ounce of trichloroethylene (TCE) in 1 million ounces of water is 1 ppm. 1 ounce of TCE in 1 billion ounces of water is 1 ppb. If one drop of TCE is mixed in a competition size swimming pool, the water will contain about 1 ppb of TCE.
Remedial investigation	The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Purpose

The purpose of this health consultation is to update the Lower Duwamish Waterway fish consumption advisory that has been in effect since July 2002. Recent fish tissue data collected as part of the on-going Remedial Investigation of the Lower Duwamish Waterway Superfund site in Seattle, Washington has prompted the Washington State Department of Health to re-evaluate the existing advisory.

It is important to note that this health consultation differs in scope and purpose from continuing Remedial Investigation (RI) studies associated with hazardous waste cleanup in the Lower Duwamish Waterway. While a risk assessment conducted under the U.S. Environmental Protection Agency and Washington State Department of Ecology's Remedial Investigation / Feasibility Study (RI/FS) process is used to support the selection of a remedial measure at a site, the health consultation is a mechanism used to provide the impacted community with information on the public health implications of a specific site identifying people for which more health actions, outreach, education, or studies are needed.

Background and Statement of Issues

The Lower Duwamish Waterway (LDW) site is located in King County, Washington on the south shore of Elliott Bay and consists of nearly 5 miles of the Duwamish River south of downtown Seattle (Figure 1). The LDW has been Seattle's major industrial corridor since it was first created by widening and straightening the Duwamish River (and forming Harbor Island) by the U.S. Army Corps of Engineers from 1913 to 1920.[1] Over 90 years of intense industrial use and municipal effluent has resulted in chemical contamination to sediments and some fish species.

The LDW site was listed on the National Priorities List (NPL) on September 13, 2001 by the U.S. Environmental Protection Agency (EPA). The NPL is EPA's list of the Nation's most contaminated hazardous waste sites, also known as Superfund sites. Four potentially liable parties collectively known as the Lower Duwamish Waterway Group (LDWG) including the Port of Seattle, King County, City of Seattle and the Boeing Company, are working with EPA and the Washington State Department of Ecology (Ecology) to investigate the nature and extent of chemical contamination in LDW sediments and evaluate cleanup alternatives. This process is commonly called a Remedial Investigation / Feasibility Study (RI/FS).

The Remedial Investigation (RI) for the LDW site is being conducted in two phases. The first phase, completed in 2003, compiled, evaluated, and summarized existing data collected during historical environmental investigations to identify locations within the LDW where early cleanup actions were suitable, identified data gaps, and prepared a work plan to complete the RI. So far, the LDWG has prepared an initial RI and has identified several sites along the LDW that have been slated for early cleanup.[2] One early cleanup has been completed, and preparation for cleanup has begun at three other early action areas. The objectives of the second phase are to conduct additional studies to fill data gaps, prepare a baseline ecological and human health risk assessment, and estimate residual health risk at the site considering completed or planned early cleanup actions.

Duwamish Fish Advisory 2002

In 2002, the Washington State Department of Health (DOH) completed a draft for public comment Public Health Assessment of the Lower Duwamish Waterway site. DOH concluded in the document, later finalized in 2003, that people who often eat resident fish from the LDW may be at risk for adverse health effects from exposure to contaminants, primarily PCBs, in fish.[a],[3] DOH recommended that no more than one eight-ounce resident fish meal per month be consumed, fish be cleaned and prepared in a manner to further reduce exposure to PCBs, and not to consume crab butter. A shellfish consumption advisory recommending no consumption was already in place along the LDW (and King County shoreline except Vashon) primarily because of sewage. This fish advisory was communicated to the public through an extensive community outreach and education plan to convey the message that utilized print and broadcast media, public meetings, fish cleaning demonstrations, sign postings, and frequent community visits by outreach professionals.

Phase 2 Sample collection and analysis

The Lower Duwamish Waterway Group collected fish, crab, and shellfish samples in August and September 2004 as part of the phase 2 RI to fill data gaps identified in the first phase of the RI. Marine tissue was collected from four areas along the LDW (Figure 2) and analyzed for many contaminants including polychlorinated biphenyls (PCBs),[4] which will be the focus of this health consultation.

Species sampled were targeted to represent seafood that may be consumed by humans and wildlife. English sole, starry flounder, three types of perch (shiner surfperch, pile perch, and striped perch), two crab species (Dungeness crab, and slender crab), and eastern soft-shell clams were the seafood species collected relevant to human health.[5] Pacific staghorn sculpin were collected specifically for ecological risk data needs.

PCBs Aroclors[b] were analyzed in all species using EPA method 8082a. Aroclor results were summed to derive total PCBs. A subset of samples was analyzed for all 209 PCB congeners[c] using EPA method 1668. The sum of these congeners represents the total amount of PCBs. Another subset of English sole samples was analyzed for PCB Aroclors to determine PCB levels in fish with skin-on versus fish with skin removed. For more information on PCBs, refer to Appendix A.

EPA has conducted quality assurance and quality control (QA / QC) on Aroclor results, but is still validating PCB congener data.[6] Data QA / QC is necessary to ensure that the analytical results are accurate and valid. Congener data for clams has been validated.

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[a] More details and the full text of the Public Health Assessment of the Lower Duwamish Waterway can be accessed at http://www.atsdr.cdc.gov/HAC/PHA/lowerduwamish/ldw_toc.html

[b] Aroclors are a trade name of varying mixtures of PCB congeners.

[c] Congeners are structural variations of PCBs that vary by the number and location of chlorine atoms on the base structure.

Discussion

Results of the recent (Phase 2) and historical tissue PCB analyses are presented in Table 1. Total PCBs are reported as either the sum of Aroclor mixtures, or the sum of all 209 PCB congeners. PCB levels are highest in whole body fish and crab hepatopancreas compared with fish fillets or crab muscle. Crab muscle and clam tissue have lower PCB levels than fish fillets. PCB levels in English sole and shiner surfperch appear to be higher at three downstream locations (Areas 1-3) compared to one upstream location (Area 4) [Figure 2].

Generally, average PCB levels are higher in phase 2 samples compared with historical samples of the same species and tissue type. The reason for this increase has not yet been determined.

Table 1. Recent and historical average polychlorinated biphenyl (PCB) concentrations in fish and crab tissue collected in the Lower Duwamish Waterway Seattle, Washington

Phase 2 samples collected August - September 2004							Historical samples collected 1992-1999 [a]		
Fish or Crab type	**Tissue type**	**C / I**	**N**	**Mean PCBs Aroclor ug/kg**	**N**	**Mean PCBs Congeners ug/kg**	**C / I**	**N**	**Mean PCBs Aroclor ug/kg**
English Sole	Whole body	C	21	3,120	7	2,024	I	3	958
	Fillet with skin	C	7	1,426	7	955			NA
	Fillet with skin	I	10	849	NA	NA			NA
	Skinless fillet	I	10	716	NA	NA	C / I	18 / 9	267 [b]
Starry Flounder	Fillet with skin	C	1	450	1	300			NA
	Whole body	C	3	570	1	458			NA
Pile Perch	Fillet with skin	C	1	300	1	192			NA
Striped perch	Fillet with skin	C	1	630	1	442	C / I	8 / 1	160
Shiner surfperch	Whole body	C	24	2,582	9	3,190	C	3	496
Dungeness crab	Muscle	C	7	240	3	136	I	3	130
	Hepatopancreas	C	3	4,667	2	3,619	I	1	1,647
Slender crab	Muscle	C	12	210	4	155			NA
	Hepatopancreas	C	4	1,818	2	919			NA
Eastern soft-shell clam	Clam tissue (minus shell)	C	14	143	9	222			NA

NA –Not analyzed
N = number of samples
C = composite sample (tissue from five or more animals homogenized as one sample)
I = individual sample (tissue from one organism per sample)
a - Values including a portion of samples caught in waterways east and west of Harbor Island (outside the LDW site

boundaries)
b -Weighted average of composite and individual samples

Data appropriate for Fish Advisory Update

Regardless of the cause, recent data collected as part of the phase 2 RI indicate that PCB levels in resident fish and crab were higher than earlier sampling efforts. Given that previous PCB levels were high enough to trigger a fish consumption advisory and extensive community outreach/education, an update to the health message to the community is considered in this health consultation contingent upon evaluation of the appropriateness of these data.

Data were considered appropriate for the following reasons:

- EPA conducted QA/QC evaluation of Aroclor analytical results and determined that the data are valid. Although congener data are still undergoing QA/QC evaluation, they lend support that PCB levels in LDW resident fish are indeed elevated.
- The sampling design was largely geared to collect available resident fish and crabs likely to be harvested and eaten by humans at a time of year (summer) when people were most likely to catch fish or crab from the LDW. Therefore, resident fish species sampled are representative of what people could eat from the LDW.
- The sampling design incorporated the use of a composite sampling scheme for all species minimizing the analytical measurements required to approximate an average concentration of contaminant (PCBs) in fish and crab tissue.
- PCB levels were consistently elevated above 200 ppb in all tissue types and at all areas sampled. This PCB level approximates a decision point above which DOH may recommend that people avoid eating seafood.

Determining Allowable Consumption Rates

DOH calculated fish meal limits using a method outlined in EPA's "Guidance for Assessing Chemical Contaminant Data for Use in Fish Consumption Advisories."[7] By using the known concentration of a contaminant in a fish species, it is possible to calculate an allowable amount that can be eaten for that species without exceeding the reference dose (RfD) for that contaminant.

The RfD is defined as an exposure dose at or below which adverse noncancer health effects are not likely. The RfD for PCBs (0.00002 mg/kg/day) is based on adverse immune system effects observed in exposed monkeys, but PCBs have also been shown to cause adverse developmental effects in children exposed in the womb. More information on the toxicity of PCBs is presented in Appendix A.

Exceeding an RfD does not necessarily mean that adverse health effects will occur because numerous safety factors are applied to ensure the protection of public health. If a dose exceeds the RfD, it suggests only the potential for adverse health effects. The magnitude of this potential can be inferred from the degree to which this value is exceeded.

The equation used to calculate a safe consumption rate is shown below with exposure parameters as defined in Table 2.

$$\text{8- ounce fish meals per month} = \frac{\text{RfD x (Days / Month) x BW}}{\text{Meals size x C}}$$

Table 2. Exposure parameters for calculating 8-ounce fish meal limits.

Parameter	Value	Units	Source
Reference Dose (RfD)	0.00002	mg/kg-day	EPA IRIS [a]
Days / Month	30.4	Days per month	
Body Weight (BW)	70 (adult)	kg	EPA Exposure Factors Handbook
Concentration in fish (C)	Mean contaminant concentration. Specific to fish species.	mg/kg	Phase 2 Aroclor data
Meal size	0.227	kg	kg per 8 oz.

a - Environmental Protection Agency's Integrated Risk Information System value for Aroclor 1254[8]

Applying the preceding calculation to recent LDW fish tissue data (PCB Aroclors) results in calculated meal limits of less than one meal per month for all species and tissue types (Table 3). Slender crab, Dungeness crab, and eastern softshell clams have the highest calculated meal limits at 0.9, 0.8, and 0.8 meal per month, respectively. It should be noted that DOH Office of Food Safety and Shellfish and Public Health – Seattle and King County (PH-SKC) advise against consumption of clams in the LDW and the King County shoreline (except Vashon Island) due to pathogens from urban sewage releases and potential chemical contamination.

English sole fillet and shiner surfperch whole body have the lowest calculated meal limit at 0.1 meal per month. It should be noted the recommended meal limits derived from these calculation is designed to protect a 70 kg adult eating an 8-ounce fish meal. Meal sizes for people weighing more or less than 70 kg would increase or decrease proportionally. DOH does not typically recommend fish consumption at meal limits lower than one meal per month.

Table 3. Meal limits calculated for resident fish, crab, and clams based on phase 2 PCB (Aroclor) tissue sampling Lower Duwamish Waterway site Seattle, Washington.

General Fish or Crab	Specific fish or crab and tissue type	Calculated meal limit (meal per month)
Bottomfish	English sole fillet with skin	0.1
	Starry flounder muscle [a]	0.2
Perch	Pile perch fillet [a]	0.6
	Striped perch fillet [a]	0.3
	Shiner surfperch whole body	0.1
Crab	Dungeness crab muscle	0.8
	Slender crab muscle	0.9
Shellfish	Eastern soft-shell clam	0.8 [b]

a – based on single composite sample
b – based on congener data as opposed to Aroclors. Congener data for clams has been validated.

Child Health Considerations

DOH and ATSDR recognize that infants and children may be more vulnerable to chemical exposures than adults when faced with contamination of air, water, soil, or food. This vulnerability is a result of the following factors:

- Children are smaller and receive higher doses of chemical exposure per body weight.
- Children's developing body systems are more vulnerable to toxic exposures, especially during critical growth stages in which permanent damage may be incurred.

PCBs are the main contaminant of public health concern found in LDW seafood. These chemicals have been shown to cause adverse developmental effects in children exposed in the womb.[9] For this reason, it is important for pregnant women and women considering pregnancy to pay special attention to the recommendations of this health consultation.

Conclusions

1. Recent samples of resident fish and crab in the LDW showed levels of PCBs that are higher than previous samples.

    - DOH evaluated these data as a follow-up to the Public Health Assessment written in 2002 and 2003. The Public Health Assessment recommended fish consumption limits.

2. Eating even minimal amounts of resident seafood from the LDW would result in exposure to PCBs at levels of public health concern. For this reason, consumption of LDW resident seafood (fish and shellfish that live in the LDW) is a *public health hazard*.

    - Eating frequent meals of resident fish (fish that live in the Duwamish most of the year such as English sole, flounder, and perch), crab, and shellfish may cause health problems, particularly for children and infants. Polychlorinated biphenyls (PCBs) in these fish may affect the immune system and cause learning problems in children exposed in the womb.

Recommendations

1. The fish advisory for the Lower Duwamish Waterway should be updated based on recent PCB data.

    - DOH recommends that no resident fish (e.g., English sole, starry flounder, perch) or crab be eaten from the LDW due to PCB contamination. This recommendation does not include salmon or other non-resident fish.

- In concurrence with both PH-SKC and DOH Office of Food Safety and Shellfish Programs, consumption of shellfish from the LDW should be avoided due to potential chemical and biological contamination.

2. Future updates of the LDW fish advisory should be based on long-term fish tissue monitoring trends.

3. The Washington State Department of Fish and Wildlife (WDFW) should restrict or actively discourage fishing for the resident species identified in this health consultation to support protecting public health. DOH recommends that WDFW consider non-penalty enforcement because public health is the key issue rather than resource protection.

Public Health Action Plan

1. DOH will release and communicate the following message to media outlets, community groups and individuals, and government agencies.

    - Do not eat resident fish (i.e., fish other than salmon), crab, or shellfish from the LDW.

2. DOH will prepare fact sheets and flyers in multiple languages to distribute to the community

    - Materials will be distributed while conducting community visits and outreach.

    - Materials and health consultation to be posted on DOH webpage.

3. DOH will conduct community education and outreach to communities near the LDW site, including immigrant and low-income communities in south Seattle, to communicate the updated fish consumption advisory.

4. DOH will request assistance from PH-SKC and WDFW to assist with education and outreach activities.

5. DOH will consider future updates to the fish advisory message only when it has been demonstrated that PCB levels in fish and crab have consistently decreased over time.

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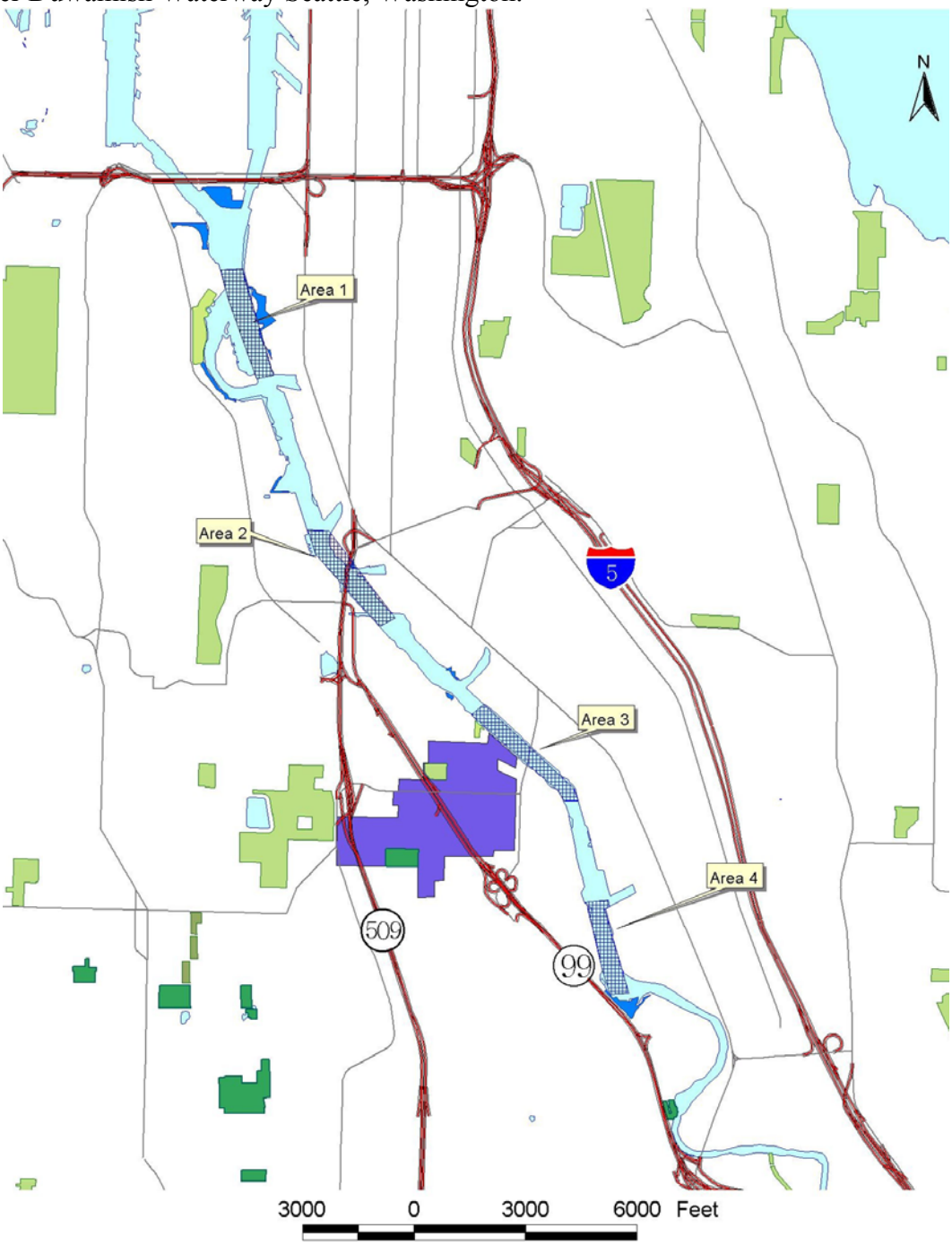
Figure 1. Lower Duwamish Waterway site location, Seattle, Washington

Figure 2. Approximate sample areas (1-4) and average PCB levels (ug/kg) in fish and crab tissue in Lower Duwamish Waterway Seattle, Washington.



Tissue Type	Area 1	Area 2	Area 3	Area 4
E. sole fillet	1465	1925	1245	710
E sole whole	3650	3850	2568	1700
Shiner surfperch whole	1387	4315	3832	795
Dungeness crab muscle	234	NA	246	240
Slender crab muscle	273	195	178	NA

Appendix A: PCB Toxicity

Polychlorinated biphenyls (PCBs)

PCBs are a group of human-made chlorinated organic chemicals that were first introduced into commercial use in 1929 as insulating fluids for electric transformers and capacitors. Other applications were soon developed that included their use in hydraulic fluids, paint additives, plasticizers, adhesives, and fire retardants. Production of PCBs in the United States stopped in 1977 following concerns over toxicity and persistence in the environment.[10]

There are 209 structural variations of PCBs, called congeners that vary by the number and location of chlorine atoms on the base structure. PCBs are often identified by one of their trade names, Aroclor. Aroclors are various mixtures of congeners defined by a four-digit number. The first two digits represent the number of carbon atoms while the second two digits give the percent by weight of chlorination for the congeners in that mixture. In general, PCB persistence and toxicity increases with the degree of chlorination in the mixture.

Liver toxicity has been demonstrated in animals given high doses of PCBs. Liver toxicity and developmental effects are also well documented in residents of Taiwan and Japan exposed to relatively high levels of PCBs through ingestion of contaminated rice oil. However, the association of these effects with PCB exposure is complicated by concurrent exposure to chlorinated dibenzofurans.[9]

While the "rice oil" incidents in Taiwan and Japan provide good evidence of PCB toxicity in humans, recent studies demonstrate that developmental effects can occur at lower levels of PCB exposure. Deficits in neurobehavioral function in children exposed *in utero* represent the most compelling evidence that environmental exposure to PCBs have caused adverse health effects in humans. Studies of various human populations exposed to PCBs, primarily through the ingestion of fish, have demonstrated deficits in neurobehavioral function. Learning deficits were maintained in the children of one Lake Michigan fish-eating cohort through 11 years of age. Animal studies have also shown adverse effects on development following prenatal exposure of the fetus.[11]

Thyroid dysfunction has also been associated with PCB exposure. Several *in vitro* and animal studies have shown a reduction in thyroid hormone (thyroxine) levels in response to PCB exposure. A study in rats exposed *in utero* to PCBs found hearing deficits concurrent with decreasing thyroxine levels. This finding suggests that interference with thyroxine levels could be a mechanism for the developmental effects associated with children exposed to PCBs prior to birth. The potential for PCBs to disrupt hormone function, including the endocrine system, has been suggested as a mechanism for the reproductive effects of PCBs seen in animals. Some human epidemiological studies provide support for the reproductive toxicity of PCBs including effects on menstrual cycles in women and male fertility.[9]

ATSDR has recently reviewed its minimal risk level (MRL) considering the more recent human developmental studies discussed above. This review concluded that immune system effects seen in monkeys still represent the most sensitive toxic endpoint of PCB exposure. Further, ATSDR concluded that the existing MRL based on this endpoint should not change and would be

protective of the developmental effects found in the more recent human epidemiological studies discussed above.[9]

While high dose animal studies demonstrate that PCBs can cause liver tumors in rats, *evidence that PCBs can cause cancer in humans is conflicting*. Some studies have linked human exposure to organochlorines with breast cancer while other studies have found no association. Other studies suggest a link between PCB exposure in humans and non-Hodgkin's lymphoma (NHL) based on higher PCB blood serum levels in NHL patients versus controls. One recent analysis of a large cohort of workers exposed while manufacturing PCB containing transformers showed no increase in mortality despite high PCB blood serum levels. The previously mentioned rice oil-poisoning incident in Taiwan did not reveal elevations in cancer mortality. However, an examination of residents similarly exposed in Japan did show an increase in mortality from liver cancer.

Certification

This Health Consultation was prepared by the Washington State Department of Health under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the health consultation were begun.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health consultation and concurs with the findings.

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