Public Health Assessment

Final Release

PORTLAND HARBOR: RECREATIONAL USE
PORTLAND, OREGON

EPA FACILITY ID: ORSFN1002155

Prepared by the
Oregon Health Authority
Environmental Health Assessment Program (EHAP)

SEPTEMBER 12, 2011

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR's Cooperative Agreement Partner pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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This report is being published as a final draft. Previously this report was released for public comment, and all comments received before May 20, 2010, have been addressed here. Appendix A describes in detail how public comments were addressed. Prior to public comment, an earlier draft of this report was reviewed by government agency partners, including the Environmental Protection Agency (EPA), Oregon's Department of Environmental Quality (DEQ), and local Native Tribes. Their comments were incorporated prior to release to the general public. If you have more questions about this report, please contact us via telephone 1-888-290-6767, via email at: info.ehap@state.or.us, or via postal mail addressed to:

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Portland, OR 97232

Foreword

The Environmental Health Assessment Program (EHAP) within the Oregon Public Health Division (PHD) has prepared this Public Health Assessment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR is part of the United States (U.S.) Department of Health and Human Services, Public Health Service. The mission of ATSDR is to serve the public by using the best science, taking responsive actions, and providing trusted health information to prevent harmful exposures and disease related exposures to toxic substances. This Public Health Assessment was prepared in accordance with ATSDR methodology and guidelines.

An ATSDR Public Health Assessment reviews available information about hazardous substances at a site and evaluates whether exposure to them might cause any harm to people. ATSDR conducts a Public Health Assessment for every site on or proposed for the National Priorities List (the NPL, also known as the Superfund list). A Public Health Assessment is not the same as a medical exam or a community health study.

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Introduction

The Environmental Health Assessment Program's (EHAP's) top priority is to ensure that the communities using the Portland Harbor Superfund Site Study Area have the best information possible to safeguard their health.

Under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR), EHAP evaluates the public health risks associated with chemical contamination at Superfund sites located within Oregon. EHAP is housed in the Oregon Health Authority Office of Environmental Public Health.

The Portland Harbor Superfund Site Study Area is a roughly 9.8-mile stretch of the Lower Willamette River starting in the north at the confluence with the Columbia River and ending near the Steel Bridge in downtown Portland, Oregon. Portland Harbor is an operational, industrial port that has been modified to accommodate ocean-going vessels. The landscape has been heavily modified for industrial and urban development.

Extensive chemical contamination of Portland Harbor led to its listing as a Superfund Site in the year 2000. In 2006, EHAP completed a Public Health Assessment that focused on eating fish and crayfish as the primary way that chemicals from the site could put people's health at risk. EHAP found that eating more than the recommended amount of resident fish species from the Harbor was a public health hazard. The 2006 report and its findings are available online at http://www.atsdr.cdc.gov/HAC/pha/PortlandHarbor/PortlandHarborPHA032206.pdf. EHAP continues to recommend that people heed the fish advisories in effect for Portland Harbor, which state:

- Women of childbearing age (18-45), particularly pregnant or breastfeeding women, as well as children and people with weak immune systems, thyroid or liver problems, should avoid eating resident fish from Portland Harbor, especially carp, bass, and catfish. Resident fish are those fish that stay within a small territory for their entire lives, and do not migrate.
- Healthy women beyond childbearing age and healthy adult males should restrict the amount of resident fish eaten from Portland Harbor to no more than one 8-ounce meal per month.

The current fish advisory for Portland Harbor can be found at www.healthoregon.org/fishadv.

	2011 Public Health Assessment This Public Health Assessment is focused on recreational users and anglers who may come into contact with chemical contamination found in beach sediment, river bottom sediment, and/or surface water. The federal Environmental Protection Agency (EPA) is the agency responsible for clean-up of the Portland Harbor Superfund Site and has given EHAP the data used in this report in order to assess the public health risks associated with the site.
Conclusions	EHAP reached *three* important conclusions in this Public Health Assessment:
Conclusion 1	People who regularly recreate (i.e., boat, swim, beach comb, etc.) at the former GASCO site beach over several years, may be exposed to polycylic aromatic hydrocarbons (PAH)s at levels that may increase their risk of developing cancer at some time in their lives. However, it is unlikely that this beach is presently being used recreationally on a regular basis.
Basis for Decision	The PAH levels in the sediment at the beach located on the west bank of the Willamette River just south of river mile 6, also known as the former GASCO site, are high enough to elevate cancer risk to levels that are unacceptable for children and adults. This determination is based on assumptions that an adult or child visits this particular beach 94 days or more per year over the course of 30 or more years. It is unlikely that anyone is using the beach this often at the present time, but frequency could increase in the future if site conditions change.
Next Steps	EHAP recommends that the EPA and Responsible Parties: • Ensure that this beach is cleaned up to reduce PAH concentrations • Install and maintain shore- and water-facing signs on this beach that warn of the potential health risk from recreating on or generally coming into contact with the sediment. EHAP will consult with DEQ and EPA about language and placement of these signs. People can reduce their risk of developing cancer if they: Avoid the beach most contaminated with PAHs. The area is on the west bank of the Willamette River just south of river mile 6 on the former GASCO site (see Figure 2 for location).
Conclusion 2	Swallowing or touching chemical contaminants in water, beach sediment, and bottom sediment at other beaches is *not* expected to harm the health of people who recreate (i.e., boat, swim, beach comb, etc.) or work within the Portland Harbor Superfund Site.

Basis for Decision	Based on sampling data available at the time this report is published, the concentrations of chemicals measured in water, beach sediment, and river bottom sediment (*except the beach mentioned in Conclusion 1*) are too low to harm the health of people (including children) who use the area for work or recreational purposes. The Oregon Department of Environmental Quality (DEQ) is continuing to collect environmental data at sites upland from the water's edge. EHAP will review the results and, if necessary, recommend future actions to safeguard public health.
Next Steps	If future environmental data reveal potential health hazards not addressed in this report, EHAP will address them in separate assessments as the data become available. EHAP supports EPA's efforts to clean-up of contaminated sediments in the Portland Harbor Superfund Site. This will help reduce contaminant levels in fish over the long-term.
Conclusion 3	Although not site-related, water contact of any kind near combined sewer overflow (CSO) areas during the rainy season could cause bacteria-related illness.
Basis for Decision	Bacteria concentrations from sewage measured in the water around CSO areas following a rain storm could be high enough to cause bacteria-related illness in people who swallow small amounts of water while swimming or otherwise contacting water from the harbor. Call the City of Portland's Bureau of Environmental Services at 503-823-5328 for CSO locations. The CSO website is located at: http://www.portlandonline.com/bes/index.cfm?c=31030

Next Steps	We are taking the following actions:
	• EHAP will consult with the City of Portland to ensure that signs marking CSO locations and the hazards associated with swimming near CSO areas are well designed, well placed, and well maintained.
	• EHAP supports the City of Portland's continued efforts to reduce the amount of sewage that spills into the Willamette River through CSOs.
	• EHAP recommends that people who use the Portland Harbor Superfund Site for work, recreation, or fishing:
	  o Avoid swimming in or contacting the water from CSO areas following rain storms
	  o Thoroughly wash hands after contacting water from the Lower Willamette River before eating to avoid bacteria-related illness
	  o Thoroughly wash all body surfaces that come into contact with the water the Lower Willamette River to avoid bacteria-related illness
	  o Thoroughly wash any recreational equipment such as kayaks, oars, paddles, water skis etc. after use in the Lower Willamette River to avoid bacteria-related illness

For More Information	Contact the Environmental Health Assessment Program by e-mail: ehap.info@state.or.us, or by calling 971-673-0977. If calling from outside the Portland Metro area, call toll free: 1-877-290-6767.

Purpose and Health Issues

Under cooperative agreement with ATSDR, EHAP conducted this Public Health Assessment (PHA) for the Portland Harbor Superfund Site. EHAP and ATSDR are committed to providing a comprehensive assessment of potential health risks to communities who use Portland Harbor. This PHA evaluated the public health risks that recreational users and anglers may face from direct contact with beach sediment, river bottom (in-water) sediment, and surface water. ATSDR's mandate is to specifically assess the public health risks that may result from exposure to chemical contaminants. However, because bacterial contamination at the Portland Harbor Superfund Site has been well documented and is of concern to the community, EHAP also evaluated health risks from contacting bacteria in the river water.

Eating fish contaminated with polychclorinated biphenyls (PCBs) is by far the most significant health risk from chemical contamination at this site. Therefore, in this report, EHAP has reiterated the important conclusions made in a previous PHA, completed in 2006, that specifically focused on eating Portland Harbor fish and crayfish. The previous assessment found that eating resident fish species from the harbor is a public health hazard. Resident fish are those fish that live their entire lives in a small territory and do not migrate. Examples include bass, carp, and catfish. This does not include migratory fish like salmon or steelhead. The previous report can be found at http://www.atsdr.cdc.gov/HAC/pha/PortlandHarbor/PortlandHarborPHA032206.pdf [1].

Transient (homeless) populations that live outdoors along Portland Harbor may come into contact with contaminants in ways not addressed in this report. Notable examples include bathing in and drinking groundwater from seeps along the river. The extent to which this population may come into contact with Portland Harbor contaminants through these unique pathways is not clear. EHAP is evaluating whether an additional follow-up document that addresses health risks specific to transients would be helpful to that population or those who serve them.

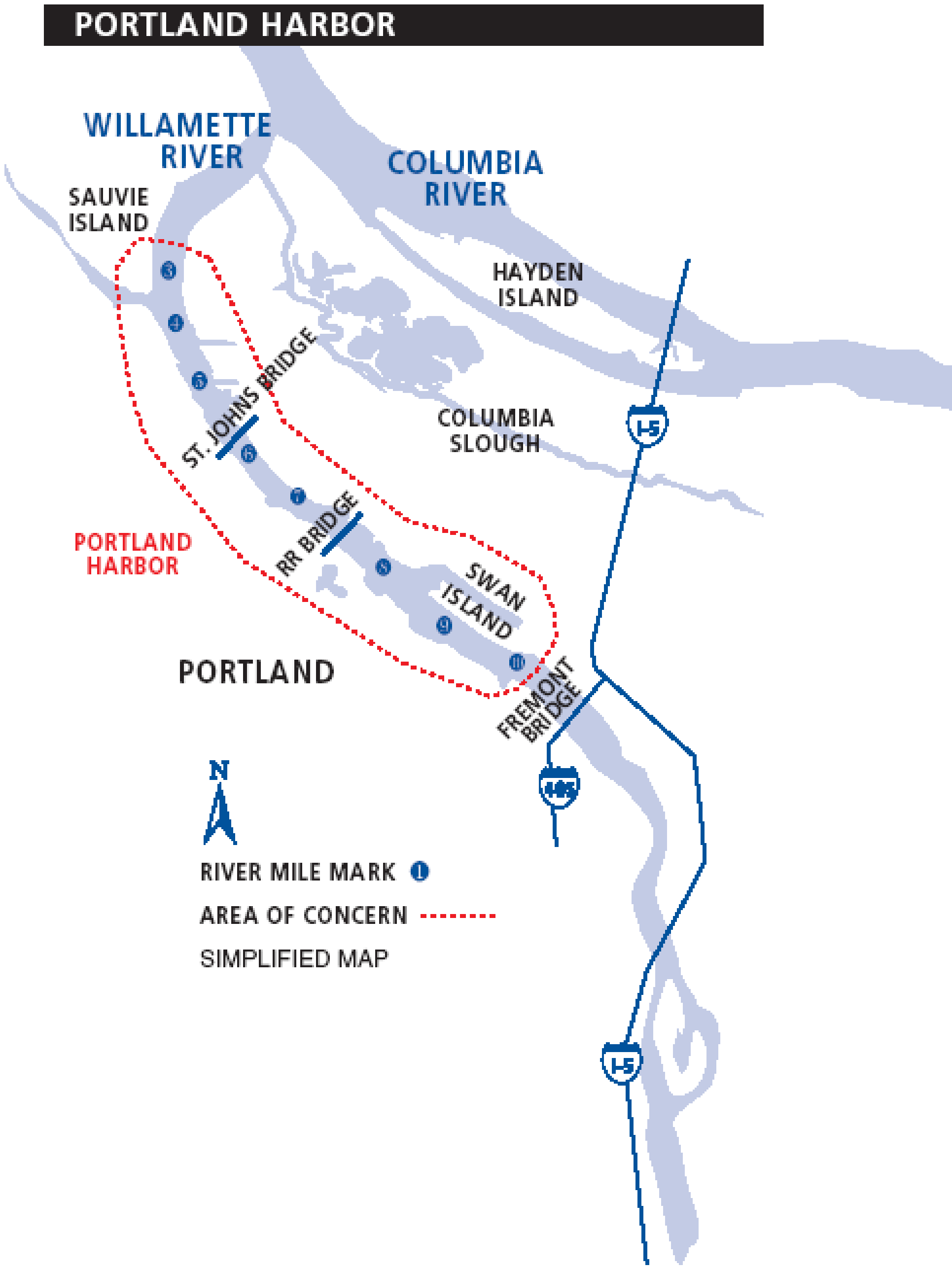
Background

Site Description

Portland Harbor is located in Multnomah County, Oregon, comprised of the Lower Willamette River. On December 1, 2000, a portion of Portland Harbor was listed on the EPA's National Priorities List (NPL). The initial study area for the site was a nearly six-mile stretch of the Willamette River, from the southern tip of Sauvie Island [river mile 3.5] to Swan Island [river mile 9.2]. The area has since been expanded and now extends from river mile 2 to river mile 11.8 (Figure 1). The portion of the river that was placed on the NPL is the most industrialized area of the Willamette River and lies entirely within the city limits of Portland, Oregon.

The Willamette River begins in the Cascade Mountains and flows generally north to its confluence with the Columbia River [2]. The last 26.5 miles of the Willamette River before the confluence is wide and slow moving, and water levels fluctuate daily due to tidal reversals. This section of the river was generally shallow historically, but now the last 12 miles of the Willamette River has an average depth of 45 feet with a maximum of 140 feet. This greater depth is the result of regular dredging by the U.S. Army Corps of Engineers to allow large ocean-going ships to use Portland Harbor. The portion from river miles 3 to 10 is where most of the sediment from further upstream in the Willamette River accumulates.

Figure 1. Portland Harbor Study Area



Site History

In an initial PHA released in 2002, ATSDR concluded that the greatest health risks from chemicals at the Portland Harbor site were from eating contaminated fish[3]. These conclusions were very general, because little data had been collected at that time on the chemicals or fish species of concern at the site. After EPA had collected this information, EHAP (then called SHINE) conducted a second PHA which provided a comprehensive evaluation of the public health effects of eating fish and crayfish from Portland Harbor. This PHA was conducted under cooperative agreement with ATSDR and was released on March 22, 2006 [1].

Commercial and industrial activities are an integral part of Portland Harbor. Past and present sources of pollution have contaminated the area with metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, dioxins/furans, petroleum products, and other chemicals. A group of potentially responsible parties, known as the Lower Willamette Group (LWG), has funded most of the Remedial Investigation and Feasibility Study (RI/FS) that addresses these contaminants.

The EPA and the Oregon Department of Environmental Quality (DEQ) co-manage the cleanup of the Portland Harbor NPL Site. EPA has primary responsibility for the in-water portion and DEQ for the upland sources of contamination. These two agencies are also working closely with nine natural resource trustees. The trustees are designated by law to act on behalf of the public or tribes to protect and manage natural resources such as land, air, water, fish, and wildlife. Among the trustees are six tribes - the Confederated Tribes of the Grand Ronde (CTGR), Confederated Tribes of Siletz Indians (CTSI), Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Confederated Tribes of the Warm Springs Reservation of Oregon, the Nez Perce Tribe, and the Confederated Tribes and Bands of the Yakama Nation. The Oregon Department of Fish and Wildlife (ODFW), the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Fish and Wildlife Service (USFWS) are the state and federal government natural resource trustees.

Site Visits

EHAP and ATSDR visited Portland Harbor numerous times between 2002 and 2010 by boat, car, and foot. EHAP staff interviewed numerous individuals about fishing access, transient camp locations, recreational sites and activities, fish and meal preference, fish consumption and preparation practices, and other aspects relevant to this and previous assessments. EHAP staff toured Portland Harbor by boat with Willamette Riverkeepers, Multnomah County Vector Control, EPA Region 10, and DEQ.

Demographics

ATSDR's public health assessments usually have a section describing the demographic characteristics of the population within a mile of a Superfund or hazardous waste site. This is to determine, if there are environmental and social justice issues to consider, and to understand how to best engage and communicate with local communities. It is assumed that those living closest to a site would have the greatest contact with site contaminants. However, because very little of the area surrounding Portland Harbor is zoned for residential use, the potential risks are to people who recreate and work near the site. Therefore, instead of the usual demographic evaluation, this PHA will address the relevant "at risk" populations.

For this PHA, EHAP evaluated the possible health risk for all people who recreate on and along this area of the Willamette River. Recreational users include people from a variety of hobbiests and special interest groups and not simply those living near the river. Although transient camps have been observed along the banks of Portland Harbor, this population is difficult to characterize or follow since they move often. The available information on transient populations suggests that their primary concerns are survival-based.

Land and Water Use

The habitat along river miles 2 to 11.8 (the current Portland Harbor site study area) has been substantially altered due to urban and extensive shipping industry development [4]. Shoreline features include steeply sloped banks covered with riprap or constructed bulkheads, with manmade structures such as piers and wharves extending out over the water. This area of the river is largely devoid of trees and other vegetation along the riverbanks.

The habitat of the rest of the lower Willamette River is not as degraded as the study area. This is indicated by the gently sloping, well-vegetated banks at Ross Island, the mouth of Stephens Creek, Powers Marine Park, the mouth and lower reaches of Johnson Creek, Multnomah Channel, Kelley Point Park, and the lower reaches of the Columbia Slough. The first four locations are upstream and the last three are downstream from the current study area.

The study area is heavily industrialized. Some of the historical or current industrial operations include: marine construction, bulk petroleum product storage and handling, construction material manufacturing, oil gasification plant operations, pesticide/herbicide manufacturing, agricultural chemical production, battery processing, liquid natural gas plant operations, ship maintenance, repair and refueling, barge/rail car manufacturing and metal scrapping, and recycling. Within or near the Portland Harbor study area, there are numerous active investigations or cleanups currently being performed under DEQ oversight, including the investigation of several City of Portland storm water outfalls.

There are residential areas intermixed or close by these riverside industries, including the St. John's neighborhood, Overlook Park, and the communities of Linnton and University Park. Recreational activities in this part of the Willamette River include fishing, boating, swimming, and water skiing. Cathedral Park and Swan Island serve as boat launches and bank fishing locations (observed during site visits). During all of our site tours, we observed tents, makeshift dwellings, fire pits and discarded debris, which provided evidence of people living along the riverbanks.

Discussion

This section explains EHAP's assessment process used to develop this report's conclusions on how contaminants at this site may affect the public's health. It includes a description of information sources that EHAP used and how that information was combined and analyzed. This section also presents, in detail, the rationale behind each of the conclusions of this PHA.

Data Use and Sampling Methods

In order to understand whether or not contaminants at the Portland Harbor Superfund Site pose a risk to recreational users and workers, it is important to know the concentration of contaminants in various "media" (beach sediment, in-water [river bottom] sediment, and surface water). This information is gathered by collecting samples of the environmental media from areas where people have access to them and measuring the amount of various contaminants.

Environmental sampling data included in this report are from the Comprehensive Round 2 Report prepared by the Lower Willamette Group (LWG) under the direction of the EPA [5]. The EPA collected water, soil, sediment, and fish samples throughout the 9.8-mile length of the current study area from 2002-2005.

The LWG used EPA-approved laboratory methods to measure the concentration of chemicals in the environmental samples. EHAP believes that the sampling data were of adequate quality to evaluate possible hazards and make public health decisions.

Nature and Extent of Contamination

The EPA chose specific chemicals to be measured based on the types of chemicals and chemical byproducts historically and currently used and produced at industrial sites along the harbor. The EPA also measured chemicals that are commonly found in urban areas and at other hazardous waste sites. These included metals such as lead, mercury, and arsenic; organic chemicals such as PCBs; and pesticides. The complete list of chemicals detected in the three media (beach sediment, river bottom sediment, and surface water) can be found in the Tables C1-C3 in Appendix C.

EHAP compared the maximum sample concentrations for each chemical detected against a standard comparison value (CV). EHAP used CVs from a variety of sources including ATSDR and the EPA. These comparison values are media-specific and represent the concentration of a given contaminant that scientists believe people could contact every day for their entire lives without any health problems. Because most people will not contact those media that often, these CVs are conservative estimates, and therefore are protective of health. See Appendix B for more detailed explanations and definitions of the CVs used.

When the concentration of a contaminant in a medium (beach sediment, river bottom sediment, or surface water) was higher than the CV for that contaminant, it became a "contaminant of potential concern" or COPC. Since the CVs are designed to be protective of health, COPCs were looked at more closely in the next stage of the assessment. When the concentration of a contaminant in a medium was lower than its comparison value, EHAP concluded that people's health would not be affected by coming into contact with it. Contaminants whose concentrations were below the CVs were not evaluated further in this assessment.

The COPCs identified for beach sediment included copper, seven polycyclic aromatic hydrocarbons (PAHs), and PCB Aroclors. The seven PAHs are benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene. The beach with the highest levels of PAH contamination in the sediments is just south of river mile 6 on the west side of the river and is marked as “Highest PAHs” on the map in Figure 2. The beach with the highest concentration of copper was located just south of Cathedral Park on the same side of the river as the park and is marked “Highest Copper” on the map in Figure 2. The beach with the highest levels of PCB Aroclors is just south of river mile 2 on the east side of the river and is marked “Highest PCBs” on the map in Figure 2.

It should be noted that one composite sediment sample consisting of 12 supsamples was collected from each beach. The longest of these beaches is just under half a mile; most are much less than a quarter mile in length. None are more than 50 feet wide. EHAP considers the results to be representative of contaminant levels.

EHAP identified 19 COPCs for in-water sediment. These included 2 metals (arsenic and lead); 6 PAHs; bis(2-ethylhexyl)phthalate; pentachlorophenol; 3 groupings of PCBs; dioxin; and 5 pesticides.

For surface (river) water, arsenic was the only COPC that EHAP identified. See Table 1 for a comprehensive list of COPCs identified for all media at the Portland Harbor Superfund Site.

Portland Harbor Beach Sampling Locations

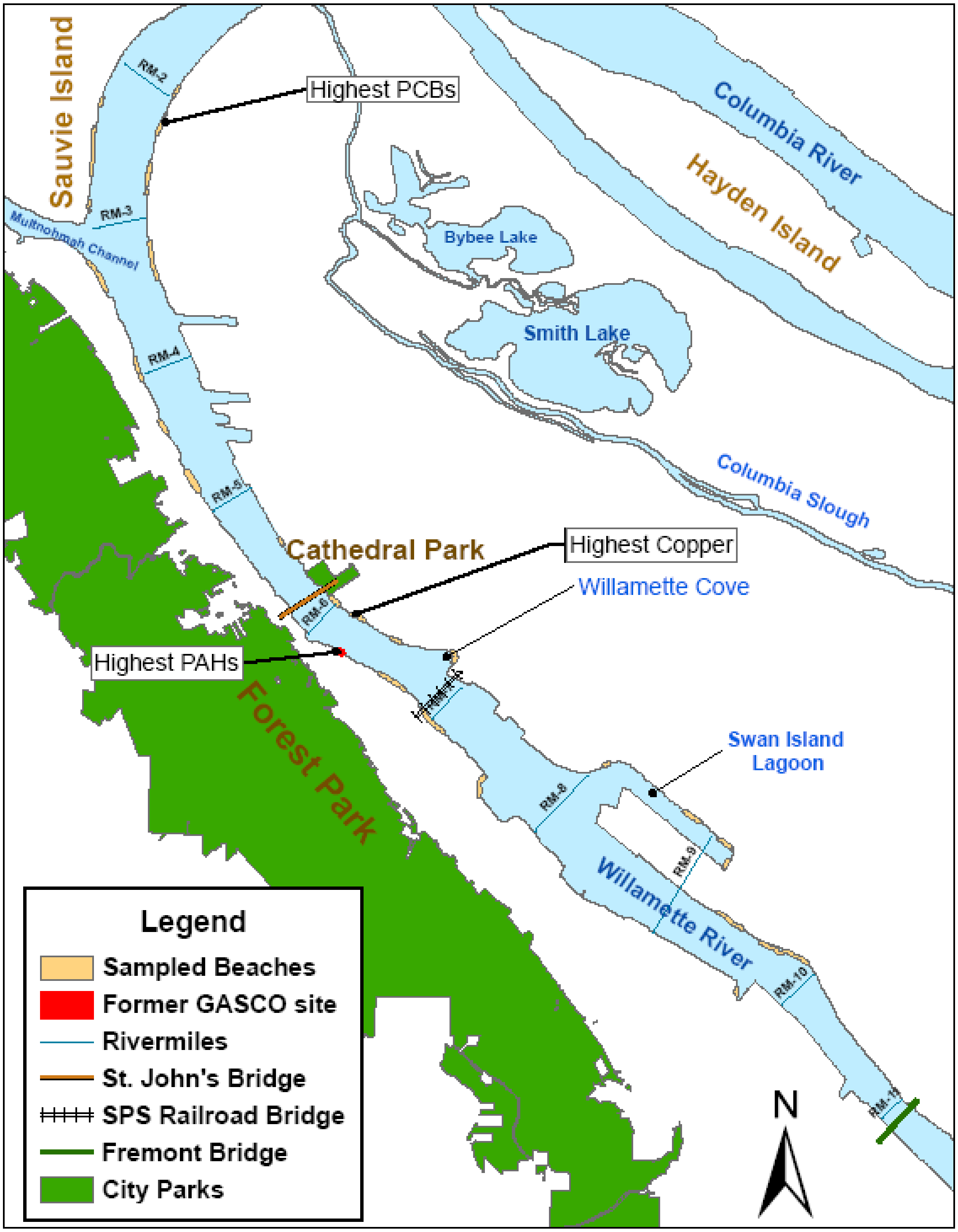


Figure 2. Beach sediment sampling locations

Table 1. Contaminants of Potential Concern (COPCs) in All Media at Portland Harbor

Class of Chemical	Contaminant of Potential Concern	Beach Sediment	In-Water Sediment	Surface Water
Metals	Arsenic		X	X
	Lead		X	
	Copper	X		
Polycyclic Aromatic Hydrocarbons (PAHs)	Benzo(a)anthracene	X	X	
	Benzo(a)pyrene	X	X	
	Benzo(b)fluoranthene	X	X	
	Benzo(k)fluoranthene	X	X	
	Chrysene	X		
	Dibenzo(a,h)anthracene	X	X	
	Indeno(1,2,3-cd)pyrene	X	X	
Phthalates	Bis(2-ethylhexyl) phthalate		X	
Phenols	Pentachlorophenol		X	
Polychlorinated Biphenyls (PCBs)	Total PCB Aroclors	X	X	
	Total PCB Congeners		X	
	Total PCBs without dioxin-like congeners		X	
Dioxins	Total Dioxin TEQ*		X	
Pesticides	Aldrin		X	
	Dieldrin		X	
	Total DDDs		X	
	Total DDEs		X	
	Total DDTs		X	

*TEQ = Toxic Equivalency Quotient refers to the sum of the toxicity of all of the various dioxin and dioxin-like compounds relative to the most toxic member of the dioxin family: 2,3,7,8-tetrachlorodibenzo-p-dioxin. DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane

Exposure Pathways

In order for a chemical contaminant to harm human health, there must be a way for people to come into contact with the chemical. An "exposure pathway" describes the way that a chemical moves from its source to physically coming into contact with a person. An exposure pathway has 5 elements:

1) A contaminant source or release
2) Movement of the chemical through the environment to a place where people could come into contact with it
3) A place where people could contact the contaminant
4) Route of exposure to a contaminant (breathing it, swallowing it, absorbing it through skin, etc.)
5) People that come in contact with the contaminant(s)

An exposure pathway is called "completed" if all 5 of the elements are known to be in place and occurring. If it is unknown whether one or more of the elements is in place, then it is called a "potential" pathway. If it is known that one of the 5 elements is not in place, then that pathway is "eliminated."

Completed Pathways

Table 2 summarizes the completed exposure pathways that EHAP identified for the Portland Harbor Superfund Site.

Table 2. Completed exposure pathways

Pathway	Time	Source	Media and Transport	Point of Exposure	Route of Exposure	Exposed Population
Contact with beach sediment	Past, present, future	Industrial and municipal discharges	Beach sediment	Parks and shoreline access areas	Swallowing, touching the skin	Recreational beach users, anglers, transient users, tribal users, dockside workers
Contact with surface water	Past, Present, Future	Industrial and municipal discharges	Surface water	River	Swallowing, touching the skin	Recreational swimmers, anglers, transient users, tribal users, and occupational divers
Contact with in-water sediment	Past, Present, Future	Industrial and municipal discharges	In-water sediment	River	Swallowing, touching the skin	Anglers, tribal users, occupational divers
Fish and crayfish consumption	Past, Present, Future	Industrial and municipal discharges	Fish tissue	River	Eating	Anglers and their families including tribal fishers

In this PHA, EHAP assessed the completed exposure pathways for adult and children recreational users, and for anglers exposed to river bottom (in-water) sediment and surface water while fishing. Any health effects or risks to dockside workers, who may also contact beach sediments, are assumed to be addressed in the recreational user scenario, which is more protective of health than an occupational exposure scenario. Therefore, dockside workers were not separately considered in this assessment. The high-end exposure assumptions used for the recreational and angler scenarios ensure that tribal uses are also accounted for in this PHA.

Because children ages 0-6 represent a vulnerable, sensitive population, assessing potential health risks for this age group is assumed to protect the most sensitive adult populations.

The exposure pathway for anglers who fish the harbor, either from boats or from the shore, was assessed because these people may come into frequent contact with in-water sediment.

The fish and crayfish consumption pathway for anglers, tribal users, and their families was thoroughly assessed in a previous Public Health Assessment [1] and will not be addressed in this document.

In the exposure pathway analysis, transient users and occupational divers were identified as members of the public who also access areas within the Portland Harbor. The next two paragraphs explain why their risks were not evaluated in this document.

Transient users may come into contact with media at Portland Harbor more intimately and in more unconventional ways than other users; but their exposure to the river may include a shorter part of their lifetime than the exposure of most recreational and occupational users. Given the overall life challenges facing the transient population around the Portland Harbor Superfund Site, EHAP determined that a detailed, quantitative analysis of risks associated with short-term exposure to low levels of environmental contaminants unique to their situation was not likely to be helpful.

Occupational divers come into contact with bottom sediment much less frequently than avid anglers but in potentially larger quantities. EHAP assumed that an assessment for anglers' contact with river bottom sediment would also address the risks to occupational divers. Therefore, occupational divers were not specifically addressed in this Public Health Assessment.

Potential Pathways

Table 3 summarizes the potential pathways identified for the Portland Harbor Superfund Site. The pathway scenarios listed in Table 3 are labeled as "potential" because it is unknown if exposures are actually occurring.

Table 3. Potential exposure pathways

Pathway	Time	Source	Media and Transport	Point of Exposure	Route of Exposure	Exposed Population
Clam/ Mussel consumption	Past, Present, Future	Industrial and municipal discharges	Clam/ Mussel tissue	River	Eating	Unknown
Contact with groundwater	Past, Present, Future	Industrial and municipal discharges	Groundwater	River-side seeps and springs	Drinking	Unknown

It is unclear how many people are actually eating clams and mussels from the Portland Harbor study area. A survey conducted by the Linnton Community Center determined that some transients likely eat clams, along with a wide variety of other fish and shellfish, when they are available [6]. Tribal communities have also historically eaten freshwater clams and mussels from the area and they may do so again when availability of these food sources improves. Other groups, as yet unidentified, may also eat these clams and mussels. Therefore, EHAP will address clam consumption in a separate, focused, follow-up document following the release of this report.

It is also unclear how many people are drinking water from groundwater seeps and springs along the sides of Portland Harbor. The same survey conducted by the Linnton Community Center found that some transient users may drink this water [6]. Given the overall life challenges facing the transient population around the Portland Harbor

Superfund Site, EHAP determined that a detailed, quantitative analysis of risks associated with short-term exposure to low levels of environmental contaminants unique to their situation was not likely to be helpful.

Eliminated Pathways

Table 4 lists the eliminated pathways identified for the Portland Harbor Superfund Site. The pathways listed in Table 4 are labeled as “eliminated” because we know that some element of the exposure pathways either does not occur or the possibility of exposure via that pathway does not contribute significantly to health risks.

Table 4. Eliminated exposure pathways

Pathway	Time	Source	Media and Transport	Point of Exposure	Route of Exposure	Exposed Population
Inhalation of contaminants in beach sediment	Past, Present, Future	Industrial and municipal discharges	Beach sediment	Parks and shoreline access areas	Breathing in airborne beach sediment as dust	None
Inhalation of contaminants in surface water	Past, Present, Future	Industrial and municipal discharges	Surface Water	River	Breathing in airborne water droplets	None

It is possible that people could inhale small amounts of water or beach sediment while working or recreating on the Portland Harbor site. However, because the concentrations of contaminants in surface water and beach sediment are relatively low (in the range of parts per billion and parts per trillion), people would have to inhale a relatively large amount of airborne water droplets or sediment to have any appreciable health risks. It is unlikely that people recreating on Portland Harbor will inhale enough airborne water droplets or sediment to be harmful to health. Therefore, EHAP eliminated these pathways, and will not further address them in this report.

Public Health Implications

As described in the previous section, EHAP assessed the completed exposure pathways of COPCs for two groups of people: recreational users contacting beach sediment and surface water, with special consideration for young children; and anglers contacting beach sediment, in-water sediment, and surface water. Health implications for tribal users of Portland Harbor were considered as part of the public health assessment process. EHAP did this by using exposure assumptions about the duration and frequency of contact with known contaminants for anglers that are in the same range as those for subsistence fishers. The following section describes the contaminant doses and public health implications for people in each scenario separately, along with an explanation of the general process of dose calculation.

Dose Calculation

Dose calculation requires some assumptions about the frequency and intensity with which people contact contaminants from the Portland Harbor Superfund Site. Wherever possible, EHAP used site-specific information, but when that information was unavailable, we used default values established by ATSDR or the EPA. Where default values were unavailable, EHAP used best professional judgment. For the complete list of the exposure assumptions used to calculate doses in this report, see Appendix D. Appendix D also contains details about the methods used to calculate doses of the COPCs.

People can potentially contact contaminants from Portland Harbor through multiple media. For example, arsenic was identified as a contaminant of potential concern in water, but not in beach sediment. However, a child playing on a beach might contact arsenic in both the water and in beach sediment. Therefore, the most health protective approach is to calculate a total dose by adding the doses from the child's contact with water and beach sediment together. In this assessment, EHAP has used this additive approach to calculate dosages of contaminants.

EHAP calculated doses of COPCs to recreational users using the maximum sample concentrations of COPCs found at the Portland Harbor Site for beach sediment and surface water. Using site-wide maximum sampled contaminant concentrations is most protective of the public's health because it assumes that a person would spend all of their time at the harbor in contact with the most contaminated sediment and surface water in the entire 9.8-mile Superfund site. In reality, people are more likely to visit different areas of the site, often contacting sediment and/or surface water with lower concentrations of contaminants than the maximums. However, knowing that the beaches were sampled as composites makes it especially appropriate to use site-wide maximums to calculate doses. Composite sampling means that several samples (twelve in the case of the primary beach sampling effort [5]) of beach soil were combined into one "composite" sample. This was the case for each of the beaches sampled (see Figure 2 for sampled beaches). Composite samples are meant to represent the average contaminant concentration in beach sediment for an entire beach area. Using the site-wide maximum concentrations is like creating a hypothetical beach that had the highest concentration for all of the contaminants measured. This practice protects the health of an individual or family who may have a favorite beach.

Non-Cancer

To evaluate the risk of any health outcome other than cancer, calculated doses were compared against health guidelines (Tables 5, 6, and 9). A health guideline is the daily dose of a chemical, below which scientists consider it unlikely to harm people's health. EHAP followed ATSDR guidance [7] by using the health guidelines established by ATSDR, called Minimal Risk Levels (MRLs), whenever available. ATSDR develops MRLs for acute (14 days or less), intermediate (between 15 and 364 days), and chronic (1 or more years) exposure durations. Because exposures at the Portland Harbor Superfund Site are likely to be over the long term, chronic MRLs are most appropriate. When a specific chemical did not have a chronic MRL, the intermediate MRL was used. When neither a chronic nor an intermediate MRL was available, EHAP used an oral reference dose (RfD) established by the EPA.

If a calculated dose was higher than its health guideline for a COPC in any given scenario, that COPC was upgraded to a contaminant of concern (COC). Identification as a COC does not necessarily mean that it will harm human health, but that the identified contaminant moved up to the final step of the analysis.

Cancer

EHAP calculated the lifetime risk of developing cancer from exposure to COPCs at the Portland Harbor Superfund Site for recreational users and anglers (Tables 7, 8, 10, and 11). Cancer risk is the product of the calculated cancer dose[*] multiplied by a Cancer Slope Factor (CSF) that was developed by the EPA (or other organization if an EPA value is not available). Adding together the cancer risks from each cancer-causing COPC will give an overall added (or excess) cancer risk for people in each scenario.

Cancer risk is expressed as a theoretical probability, which can be thought of in terms of additional cancer cases in a theoretical population where everyone in that population would get the same dose of the same chemical every day over their entire lifetime. EHAP considers 1 additional case of cancer out of 10,000 (1E-04) people exposed every day for an entire lifetime to be a low risk. A cancer risk of 1 additional case out of 100,000 people (1E-05) would be a very low risk and a cancer risk of 1 additional case out of 1,000,000 people (1E-06) would be an insignificant risk. When a cancer risk for a COPC was greater than 1E-04, EHAP upgraded that COPC to a contaminant of concern (COC). Identification as a COC does not mean that increased cancer risk is expected, but that further analysis is needed.

Exposure Scenario 1: Recreational Users

In calculating the contaminant doses, EHAP assumed that children and adults would swim in the water of Portland Harbor where they could accidentally swallow some water and also have full-body skin contact with contaminants in the water. It was also assumed that adults and children would have skin contact with beach sediment and accidentally swallow some of the beach sediment. Appendix D describes all of the assumptions used in the dose calculation in greater detail.

The COPCs at Portland Harbor do not pose non-cancer health risks for adult or child recreational users. None of the COPCs had calculated doses higher than their health guideline for adult recreational users (Table 5) or child recreational users (Table 6). The PAHs without MRLs or RfDs for comparison (Table 5) can have acute non-cancer health effects, but these health effects would only occur at doses much higher than those estimated for this site. For example, scientists have found that benzo(a)pyrene, the most toxic of the 7 PAHs in Table 5, did not cause any observable health problems in pregnant mice or their offspring even at 10 mg/kg/day. This dose is 526,000 times higher than any

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[*] The method for calculating the dose for use in cancer risk assessment is slightly different than the method used to calculate doses to assess risk for non-cancer health effects. This difference is explained in more detail in Appendix D. Briefly, cancer risk accumulates over the entire lifetime of an individual; therefore, the cancer dose is averaged over a 70-year lifetime. In contrast, the non-cancer dose is averaged only over the duration of the exposure. This explains why “Total Dose” and “Total Cancer Dose” in the tables of this section yield different values for the same contaminant in the same population.

PAH dose calculated at Portland Harbor for adult recreational users, and 52,000 times higher than any dose estimated for child recreational users [8]. Therefore, EHAP does not expect recreating on any beach in Portland Harbor will cause non-cancer health problems in adults or children.

Table 5. Dose and Non-Cancer Risk to Adult Recreational Users

Chemical	Total Dose (ng/kg/day)	MRL (ng/kg/day)	MRL type	Contaminant of Concern (Y/N)
Arsenic	4	300	Chronic MRL	N
Copper	195	10,000	Intermediate MRL	N
Benzo(a)anthracene	13	---		N
Benzo(a)pyrene	19	---		N
Benzo(b)fluoranthene	14	---		N
Benzo(k)fluoranthene	11	---		N
Chrysene	17	---		N
Dibenzo(a,h)anthracene	4	---		N
Indeno(1,2,3-cd)pyrene	14	---		N
Total PCB Aroclors	0.74	20*	Chronic MRL	N

Note: Doses and Minimal Risk Levels (MRLs) are rounded to the nearest whole number.
ng/kg/day = nanograms of chemical per kilogram of body weight per day
"---" = No MRL or reference dose (RfD) has been developed for these polycyclic aromatic hydrocarbons (PAHs) [8].
PCB = Polychlorinated biphenyl
*This is the chronic MRL for Aroclor 1254 which is the most toxic commercial mixture of PCBs.

Table 6. Dose and Non-Cancer Risk to Children (1-6 years old) Recreational Users

Chemical	Total Dose (ng/kg/day)	MRL (ng/kg/day)	MRL type	Contaminant of Concern (Y/N)
Arsenic	36	300	Chronic MRL	N
Copper	1,952	10,000	Intermediate MRL	N
Benzo(a)anthracene	136	---		N
Benzo(a)pyrene	192	---		N
Benzo(b)fluoranthene	145	---		N
Benzo(k)fluoranthene	113	---		N
Chrysene	178	---		N
Dibenzo(a,h)anthracene	44	---		N
Indeno(1,2,3-cd)pyrene	145	---		N
Total PCB Aroclors	8	20	Chronic MRL	N

Note: Numbers rounded to two significant digits
ng/kg/day = nanograms of chemical per kilogram of body weight per day
MRL = Minimal Risk Level
"---" = No MRL or reference dose (RfD) has been developed for these polycyclic aromatic hydrocarbons (PAHs) [8].
Y = Yes, N = No
PCB = Polychlorinated biphenyl

However, EHAP is concerned that contact with the COPCs at Portland Harbor could result in increased cancer risks. The overall cancer risk from all COPCs was 1 in 10,000 (1E-04) for adult recreational users (Table 7), and 20 in 10,000 (2E-03) for child recreational users (Table 8). For children, exposure to benzo(a)pyrene and dibenzo(a,h)anthracene alone would result in a cancer risk greater than 1 in 10,000 (Table 8). Therefore, benzo(a)pyrene and dibenzo(a,h)anthracene were identified as COCs.

The increased cancer risk to adult and child recreational users is mainly due to one specific beach (GASCO) where PAH concentrations in the beach sediment are 100 to 200 times higher than PAH concentrations at even the second most contaminated beach. In fact, the overall cancer risk from all carcinogenic contaminants combined at the second most contaminated beach in Portland Harbor is only 0.1 in 10,000 (1E-05) for adults and 0.4 in 10,000 (4E-05) for children. In other words, the overall risk of developing health problems from recreating on beaches in Portland Harbor is very small as long as people avoid GASCO (see map in Figure 2 for location).

While people certainly access the beach at GASCO, it is unlikely that anyone is going there frequently enough to increase their cancer risk significantly at the present time. However, EHAP wanted to analyze and present the risk from recreational use at all beaches in Portland Harbor in a consistent way. The exposure frequencies and scenarios chosen are realistic for many of the beaches along Portland Harbor. Also, if conditions change at GASCO, people may go there more frequently in the future.

Table 7. Cancer Risk for Adult Recreational Users

Chemical	Total Cancer Dose§ (mg/kg/day)	Cancer Slope Factor (1/mg/kg/day)	Cancer Risk	Contaminant of Concern (Y/N)
Arsenic	1.5E-06	5.7†	9E-06 (0.09 in 10,000)	N
Copper*	8.4E-05	---	---	---
Benzo(a)anthracene	5.7E-06	0.73	4E-06 (0.04 in 10,000)	N
Benzo(a)pyrene	8.1E-06	7.3	6E-05 (0.6 in 10,000)	N
Benzo(b)fluoranthene	6.1E-06	0.73	4E-06 (0.04 in 10,000)	N
Benzo(k)fluoranthene	4.7E-06	0.073	3E-07 (0.003 in 10,000)	N
Chrysene	7.5E-06	0.0073	5E-08 (0.0005 in 10,000)	N
Dibenzo(a,h)anthracene	1.9E-06	7.3	1E-05 (0.1 in 10,000)	N
Indeno(1,2,3-cd)pyrene	6.1E-06	0.73	4E-06 (0.04 in 10,000)	N
Total PCB Aroclors	3.2E-07	2	6E-07 (0.006 in 10,000)	N
Total Cancer Risk			**1E-04 (1 in 10,000)**	**Y**

Note: Numbers rounded to two significant digits (cancer risk rounded to 1 significant digit). Complete numbers were used in calculations.
mg/kg/day = milligrams of chemical per kilogram of body weight per day
§Cancer dose is averaged over 70 year life time as opposed to exposure duration as for non-cancer dose. Also, cancer dose is expressed in milligrams/kilogram/day as opposed to nanograms/kilogram/day. This is why dose values differ between tables 5 and 6. See Appendix D for more in-depth explanation.
† This cancer slope factor incorporates more recent studies than the 1.5 mg/kg/day^{-1} cancer slope factor in EPA's IRIS database [9, 10].
* Copper does not cause cancer [11].
PCB = Polychlorinated biphenyl
Y = Yes, N= No

Table 8. Cancer Risk to Children (Cumulative Risk for First 30 Years of Life) Portland Harbor Recreational Users

Chemical	Total Cancer Dose§ (mg/kg/day)	Cancer Slope Factor (1/mg/kg/day)	Cancer Risk	Contaminant of Concern (Y/N)
Arsenic	4.3E-06	5.7†	2E-05 (0.2 in 10,000)	N
Copper*	2.3E-04	---	---	N
Benzo(a)anthracene	9.9E-05	0.73	7E-05 (0.7 in 10,000)	N
Benzo(a)pyrene	1.4E-04	7.3	1E-03 (10 in 10,000)	Y
Benzo(b)fluoranthene	1.1E-04	0.73	8E-05 (0.8 in 10,000)	N
Benzo(k)fluoranthene	8.2E-05	0.073	6E-06 (0.06 in 10,000)	N
Chrysene	1.3E-04	0.0073	9E-07 (0.009 in 10,000)	N
Dibenzo(a,h)anthracene	3.2E-05	7.3	2E-04 (2 in 10,000)	Y
Indeno(1,2,3-cd)pyrene	1.1E-04	0.73	8E-05 (0.8 in 10,000)	N
Total PCB Aroclors	9.0E-07	2	2E-06 (0.02 in 10,000)	N
Total Cancer Risk			**2E-03 (20 in 10,000)**	**Y**

Note: Numbers rounded to two significant digits (cancer risk rounded to 1 significant digit). Complete numbers were used in calculations.
mg/kg/day = milligrams of chemical per kilogram of body weight per day
§Cancer dose is averaged over 70 year life time as opposed to exposure duration as for non-cancer dose. Also, cancer dose is expressed in milligrams/kilogram/day as opposed to nanograms/kilogram/day. This is why dose values differ between tables 5 and 6. See Appendix D for more in-depth explanation.
† This cancer slope factor incorporates more recent studies than the 1.5 mg/kg/day^{-1} cancer slope factor in EPA's IRIS database [9, 10].
* Copper does not cause cancer [11].
PCB = Polychlorinated biphenyl
Y = Yes, N= No

Exposure Scenario 2: Anglers

To calculate doses of COPCs for anglers, EHAP assumed that all persons would be adults who contact surface water and in-water sediment. EHAP assumed that anglers would fish in the study area approximately 25% of the time they are fishing. Anglers do, of course, come into contact with beach sediments as well, but EHAP assumed that the adult recreational user scenario adequately addressed all the types of exposure to beach sediment that an angler would have. As discussed in the Exposure Pathway section, anglers also contact contaminants by eating the fish they catch. COPC doses from eating fish are not included in the total doses calculated here because that exposure pathway has already been addressed in great detail in a previous Public Health Assessment [1].

There were 19 COPCs identified in in-water sediment and surface water (See Table 1). Initially, doses for all COPCs were calculated using site-wide maximum contaminant concentrations for surface water and in-water sediment (See Tables 9 and 10). These doses were then screened against health guidelines (Table 9) and cancer risks were calculated (Table 10).

Table 9. Dose and Non-Cancer Health Risks to Port Harbor Anglers Based on Site-Wide Maximum COPC Concentrations

Chemical	Total Dose (ng/kg/day)	MRL (ng/kg/day)	MRL type	Contaminant of Concern (Y/N)
Arsenic	7	300	chr. MRL	N
Lead[§]	---	---		---
Benzo(a)anthracene	22	---		N
Benzo(a)pyrene	25	---		N
Benzo(b)fluoranthene	23	---		N
Benzo(k)fluoranthene	12	---		N
Dibenzo(a,h)anthracene	3	---		N
Indeno(1,2,3-cd)pyrene	18	---		N
Bis(2-ethylhexyl) phthalate	68	60,000	chr. MRL	N
Pentachlorophenol	2	1000	chr. MRL	N
Total PCB Aroclors	6	20	chr. MRL	N
Total PCB Congeners	7	20	chr. MRL	N
Total PCBs without dioxin-like congeners	7	20	chr. MRL	N
Total Dioxin TEQ	0.0015	0.001	chr. MRL	Y
Aldrin	0.11	30	chr. MRL	N
Dieldrin	0.055	50	chr. MRL	N
Total DDDs	0.28	500	int. MRL	N
Total DDEs	0.24	500	int. MRL	N
Total DDTs	1	500	int. MRL	N

Note: Numbers rounded to two significant digits or nearest whole number
ng/kg/day = nanograms of chemical per kilogram of body weight per day
MRL = Minimal Risk Level; TEQ = Toxic Equivalency Quotient refers to the sum of the toxicity of all of the various dioxin and dioxin-like compounds relative to the most toxic member of the dioxin family: 2,3,7,8-tetrachlorodibenzo-p-dioxin.
DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane
chr. = chronic exposure is considered 1 year or longer; int. = intermediate exposure is considered between 14 and 364 days.
"---" = No MRL or RfD has been developed for these PAHs [8]. PCB = Polychlorinated biphenyl; Y = Yes, N= No
[§]While lead was one of the 19 COPCs for angler exposure to in-water sediment, the process for calculating lead dose and evaluating the health risk for lead is different from all of the other 18 COPCs. Appendix E describes in detail the process of dose and risk calculation and analysis for lead.

Note that while the HQ for total dioxin TEQ[†] was 1.5 (See Table 9), the calculated dose was still 67 times lower than any dose that has been shown to harm the health of experimental animals [12, 13]. Therefore, EHAP concluded that the more significant concern for total dioxin TEQ was based on cancer risk. The non-cancer health implications of total dioxin TEQ were not evaluated further because EHAP does not expect anyone's health to be harmed by this contaminant in ways not addressed in the cancer assessment (See Tables 10 and 11).

Similarly, the PAHs without MRLs or RfDs for comparison (Table 9) can have acute non-cancer health effects, but these occur at doses much higher than those estimated for anglers at Portland Harbor. Benzo(a)pyrene, the most toxic of the 6 PAHs in Table 9, did not cause any observable health problems in pregnant mice or their offspring even at 10 mg/kg/day; this dose is 400,000 times higher than any PAH doses estimated for Portland Harbor anglers [8].

[†] See Appendix F for definition of total dioxin TEQ and related health information.

Table 10. Theoretical Cancer Risk to Anglers Based on Port Harbor Site-Wide Maximum COPC Concentrations

Chemical	Total Cancer Dose§ (mg/kg/day)	Cancer Slope Factor (1/mg/kg/day)	Cancer Risk	Contaminant of Concern (Y/N)
Arsenic	3.0E-06	5.7†	2E-05	Y
Lead*	---	---	---	---
Benzo(a)anthracene	9.2E-06	0.73	7E-06	N
Benzo(a)pyrene	1.1E-05	7.3	8E-05	Y
Benzo(b)fluoranthene	1.0E-05	0.73	7E-06	N
Benzo(k)fluoranthene	5.2E-06	0.073	4E-07	N
Dibenzo(a,h)anthracene	1.1E-06	7.3	8E-06	N
Indeno(1,2,3-cd)pyrene	7.7E-06	0.73	6E-06	N
Bis(2-ethylhexyl) phthalate	2.9E-05	0.014	4E-07	N
Pentachlorophenol	1.0E-06	0.12	1E-07	N
Total PCB Aroclors	2.5E-06	2	5E-06	N
Total PCB Congeners	2.9E-06	2	6E-06	N
Total PCBs without dioxin-like congeners	2.8E-06	2	6E-06	N
Total Dioxin TEQ	6.6E-10	1.30E+05	9E-05	Y
Aldrin	4.5E-08	17	8E-07	N
Dieldrin	2.3E-08	16	4E-07	N
Total DDDs	1.2E-07	0.24	3E-08	N
Total DDEs	1.0E-07	0.34	3E-08	N
Total DDTs	5.0E-07	0.34	2E-07	N
Total Cancer Risk			**2E-04 (2 in 10,000)**	**Y**

Note: Numbers rounded to two significant digits (cancer risk rounded to 1 significant digit). Complete numbers were used in calculations.
mg/kg/day = milligrams of chemical per kilogram of body weight per day
TEQ = Toxic Equivalency Quotient refers to the sum of the toxicity of all of the various dioxin and dioxin-like compounds relative to the most toxic member of the dioxin family: 2,3,7,8-tetrachlorodibenzo-p-dioxin.
DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane
PCB = Polychlorinated biphenyl; Y = Yes, N= No
§Cancer dose is averaged over 70 year life time as opposed to exposure duration as for non-cancer dose. This is why dose values differ between tables 9 and 10. See Appendix D for more in-depth explanation.
† This cancer slope factor incorporates more recent studies than the 1.5 mg/kg/day^{-1} cancer slope factor in EPA's IRIS database [9, 10].
*While lead was one of the 19 COPCs for angler exposure to in-water sediment, the process for calculating lead dose and evaluating the health risk for lead is different from all of the other 18 COPCs. Appendix E describes in detail the process of dose and risk calculation and analysis for lead.

The overall theoretical cancer risk to anglers based on site-wide maximum COPC concentrations is 2 in 10,000 (2E-04) (See Table 10). This is equivalent to 2 additional cancer cases out of 10,000 people that would have the same exposure over their entire lives. This is in the range of increased cancer risk that EHAP considers between a low and a moderate risk. The major contributors to this overall theoretical cancer risk (See Table 10) are arsenic (2E-05); the PAH Benzo(a)pyrene (8E-05); and the total Dioxin TEQ (9E-05), a sum of all dioxins based on their toxicity relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin. See Appendix F for more information about these three contaminants and related health information. Based on these contributions to cancer risk, arsenic, benzo(a)pyrene, and total dioxin TEQ were upgraded to COCs for anglers.

As stated before, using site-wide maximum COPC concentrations to calculate doses is most protective of health, but it likely overestimates dose and risk. In order for these calculations to be accurate, an angler would have to spend one quarter of their total fishing time in the exact spot within the 9.8-mile Superfund site study area where the maximum concentration of each of these contaminants was measured (See Table D3 in Appendix D for detailed exposure assumptions). It is much more likely that an angler will cover a larger area while fishing, coming into contact with in-water sediments from areas scattered around a mile or half-mile stretch of the river. Therefore, a more realistic way to calculate dose is to use average COPC concentrations within smaller areas of the site (See Table 11).

EHAP recalculated four sets of doses based on area-specific average concentrations in river bottom sediment for arsenic, benzo(a)pyrene, and total dioxin TEQ (see Table 11). The following areas were chosen based on the average levels of contamination in the river bottom sediment for each of the 3 COCs: river mile 6 west (highest area average for benzo(a)pyrene), river mile 7 east (highest area average for arsenic), and river mile 7 west (highest area average for total dioxin TEQ). The site-wide averages for these contaminants are shown as a reference; these recalculated doses were then used to calculate cancer risks for each of the 3 COCs and overall cancer risk for each area. These data are presented in Table 11.

Site-wide maximum COC concentrations were used to calculate the surface water contribution to total dose in each set shown in Table 11. Using site-wide maximum for surface water exposures is very conservative. This was justified because surface water contributed only an insignificant fraction of the total dose for anglers, as demonstrated in Table D9 of Appendix D.

Table 11. Theoretical Cancer Risk to Portland Harbor Anglers

River Mile Area	Chemical	Total Cancer Dose (mg/kg/day)	Cancer Slope Factor 1/mg/kg/day	Cancer Risk
RM 6 West	Arsenic	1.8E-07	5.7†	1E-06
	Benzo(a)pyrene^	2.4E-06	7.3	2E-05
	Total Dioxin TEQ	1.3E-12	1.3E+05	2E-07
	Total Cancer Risk	---	---	**2E-05**
RM 7 West	Arsenic	2.0E-07	5.7†	1E-06
	Benzo(a)pyrene	4.0E-08	7.3	3E-07
	Total Dioxin TEQ^	6.9E-11	1.3E+05	9E-06
	Total Cancer Risk	---	---	**1E-05**
RM 7 East	Arsenic^	4.3E-07	5.7†	2E-06
	Benzo(a)pyrene	1.5E-08	7.3	1E-07
	Total Dioxin TEQ	1.5E-12	1.3E+05	2E-07
	Total Cancer Risk	---	---	**3E-06**
Site-wide	Arsenic	2.2E-07	5.7†	1E-06
	Benzo(a)pyrene	1.4E-07	7.3	1E-06
	Total Dioxin TEQ	5.2E-12	1.3E+05	7E-07
	Total Cancer Risk	---	---	**4E-06**

Note: Numbers rounded to two significant digits (cancer risk rounded to 1 significant digit). Complete numbers were used in calculations.
^Contaminant with highest area average for in-water sediment
mg/kg/day = milligrams of chemical per kilogram of body weight per day
RM = River Mile
TEQ = Toxic Equivalency Quotient refers to the sum of the toxicity of all of the various dioxin and dioxin-like compounds relative to the most toxic member of the dioxin family: 2,3,7,8-tetrachlorodibenzo-p-dioxin.
† This cancer slope factor incorporates more recent studies than the 1.5 $mg/kg/day^{-1}$ cancer slope factor in EPA's IRIS database [9, 10].

None of the overall or chemical-specific cancer risks were greater than 1E-04 (1 in 10,000). EHAP does not expect any increased risk of cancer for anglers at the Portland Harbor Superfund Site due to direct contact with surface water or river bottom sediment. However, anglers should consult the previous public health assessment regarding fish consumption to learn about potential risks from eating the fish caught from the harbor [1].

Bacterial Considerations

Although this Public Health Assessment is focused on the public health implications of chemical exposures, there is some concern about bacterial contamination in the Willamette River, including the stretch running through the Portland Harbor Superfund

Site. The City of Portland's Bureau of Environmental Services Combined Sewer Overflow (CSO) website states:

> "Portland's early sewers collected sewage from homes and businesses and storm water runoff from streets in the same pipes. The mixture of sewage and storm water in this combined sewer system drained directly to the Willamette River and the Columbia Slough without treatment.
>
> In the early 1950s, the city installed large pipes next to the river and slough to intercept sewage and carry it to Portland's first sewage treatment plant, the Columbia Boulevard Wastewater Treatment Plant. When it's not raining, all the sewage goes to the plant for treatment. But during wet weather, storm water fills the combined sewer pipes to capacity and some sewage overflows." [14]

The Willamette Riverkeepers and DEQ monitor the river for *E. coli* [15]. The concentration of *E. coli* in water is reported as the "most probable number (MPN)" of *E. coli* per 100 milliliters (mL) of water (MPN/100 mL). The EPA standard for bacteria in recreational waters is 235 MPN/100 mL. At this concentration it is estimated that 8 out of 1000 people exposed in a recreational setting (i.e., swimming) would become ill.

Across all seasons from 2002-2008, the Willamette Riverkeepers and DEQ collected 100 samples from various locations within the Portland Harbor Superfund Site. The E.coli concentration ranged from 0 to 1,986 MPN/100 mL in these samples. The median over the period was 21 MPN/100 mL and the average was 80 MPN/100 mL. Seven out of those 100 samples were higher than the EPA's 235 MPN/100 mL standard, and the maximum of 1,986 MPN/100 mL was collected at the north end of the Eastside Esplanade downstream from a CSO outfall on August 10, 2006. The other 6 samples in excess of the standard were in Swan Island Channel in December of 2002 and 2003 and at the SP&S Railroad Bridge in spring, winter, and fall seasons of 2002-2005. See Figure 3 for a map of the above CSO locations. Swimming in or drinking water from locations near any CSO following rainfall (when sewage is likely to spill over into the Willamette River) could cause bacteria-related illness in people.

The city is in the process of completing Portland's Big Pipe project, which diverts all combined sewage flow to the sewage treatment plant in all but the most severe rainstorms. The west side Big Pipe project was completed in 2006. All of the current CSOs within the Portland Harbor Superfund Site are on the east side of the river, within Portland City limits. Once the east side Big Pipe project is completed, then the combined sewage overflows will be rare events. Keep in mind that CSOs extend farther north and south than the actual Superfund Site study area. Other municipalities further up or down river may also have areas where sewage overflows into the Willamette River, which is not addressed in this PHA.

In most locations and for most of the year, bacterial hazards in the Harbor do not appear to be a significant health threat. However, EHAP urges recreational users of the Portland Harbor Superfund Site, as well as other parts of the Lower Willamette River further upstream and downstream, to heed signs posted by the City of Portland discouraging swimming downstream from CSOs following rain storms when sewage overflows are most likely. EHAP also recommends that people who swim or recreate in the water from the Portland Harbor Superfund Site thoroughly wash all skin surfaces that were in contact with the water. Recreational users and anglers should especially wash hands before eating.

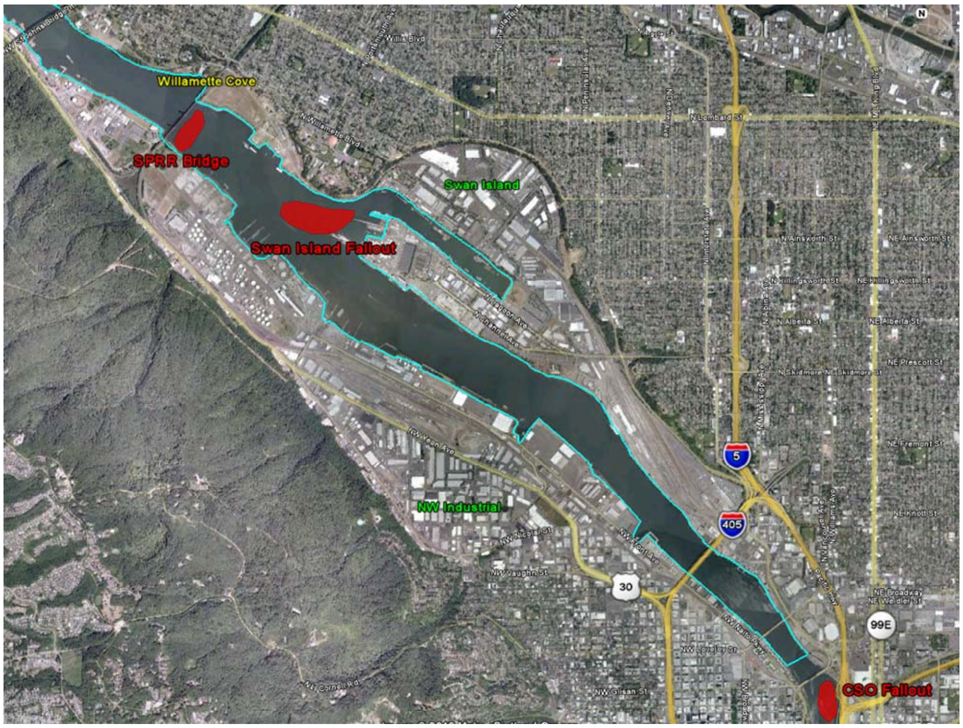

Figure 3. Locations of Portland Harbor Combined Sewage Overflow (CSO) areas (marked in red).

Uncertainties

There are many uncertainties involved in assessing public health risks from exposure to contaminants and other conditions in the environment. For example, it is impossible to know exactly how much water people accidentally swallow while swimming. The assumptions used in this report's dose calculations are based on a reasonable estimate that has been derived from studies done by the EPA. Likewise, the number of days per year that a recreational user might swim in the water at Portland Harbor will vary from one person to the next. In these types of cases, this report includes assumptions reflecting the highest exposure that is reasonably expected to occur at a site. In the presence of uncertainty, using these types of health-protective assumptions is a way to ensure that the calculated doses and subsequent public health decisions and actions are protective of the most vulnerable populations.

Neither ATSDR nor EHAP typically assess bacteria-related risks at sites. However, bacterial contamination is known to be a significant current and historical problem in the Lower Willamette River, and EHAP felt that any Public Health Assessment omitting this important issue would be incomplete. While the assessment of bacteria-related health risks in this document is less quantitative than other sections presented, EHAP is confident that the analysis presented can be used to guide public health conclusions and recommendations that protect public health.

Evaluation of Health Outcome Data

ATSDR guidance encourages that health outcome (i.e., mortality and morbidity) data (HOD) be considered in a public health assessment. This consideration is done using specific guidance in ATSDR's *Public Health Assessment Guidance Manual* [7]. The main requirements for evaluating HOD are: the presence of a completed human exposure pathway; great enough contaminant levels to result in measurable health effects; sufficient persons in the completed pathway for health effects to be measured; a health outcome database in which disease rates for population of concern can be identified [7].

This site does not meet the requirements for including an evaluation of HOD in this public health assessment. Although completed human exposure pathways exist at this site, the exposed population is not sufficiently defined, nor has a health outcome database been established to permit meaningful measurements of possible site-related health effects.

Children's Health

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

- Children are more likely to play outdoors and bring food into contaminated areas.
- Children are shorter, resulting in a greater likelihood to breathe airborne particles from indoor dust and soil, and heavy vapors close to the ground.
- Children are smaller, resulting in higher doses of chemical exposure per body weight.
- Children are more likely to mouth soil and contaminated objects; and swallow more water and soil compared to adults.
- The developing body systems of children can sustain permanent damage if toxic exposures occur during critical growth stages.

Because children depend on adults for risk identification and management decisions, EHAP and ATSDR are committed to evaluating their special interests at and around the Portland Harbor Superfund Site. It is important to note that the health-based screening values EHAP used for recreational beaches and surface water, where children are most likely to come into contact with contaminants from the site, were derived from health guidelines that incorporate a high level of protectiveness for children and other sensitive individuals.

The likelihood of experiencing health effects from exposure to environmental contaminants depends on the amount of chemical a person is exposed to and the length of exposure time. This report identified one particular beach where children's regular recreational use would constitute a potential health hazard, namely an increased theoretical risk of developing cancer.

EHAP assumed that children 0-6 years old would not be contacting in-water sediment from the bottom of the river as do avid anglers. Therefore, their exposure to contaminants in this medium would be much less.

Community Concerns

In September 2007, EHAP attended the Superfund Field Day at Cathedral Park in Portland, OR. EHAP set up a booth with an interactive display that was designed to informally engage people in talking about recreational behaviors in and around the Portland Harbor site and what their main concerns were. Participants were encouraged to place beads in jars characterizing their personal activities, or activities they have observed other community members or friends engaging in. The question posed was, "How do you (and others you know) use the river?" Seventy-eight booth participants "voted" by placing beads in whichever jar represented their categories of recreational use.

The 5 categories were:
1) Hiking/ Biking/ Picnicking (28)
2) Boating/ Sailing/ Canoeing (20)
3) Water Skiing/ Jet Boating/ Swimming (5)
4) Fishing/ Crayfish Hunting (7)
5) Other (see below) (18)

The "other" category included environmental clean-up activities, feeding ducks and birds, taking their dogs for a swim, catch & release fishing, and duck hunting.

EHAP collected a number of community concerns during the event related to recreational river use and chemical exposure. These concerns, and the actions that EHAP has taken to respond to them, are summarized below:

- People want information to understand current and future health effects from eating fish caught near the site, and living and playing near the Superfund site.
    - The 2006 Public Health Assessment contains a comprehensive evaluation of the health effects of eating fish from Portland Harbor [1].
    - This report specifically addresses recreational activities such as wading, swimming, and playing on beaches along the Portland Harbor Superfund Site as well as the health effects of exposure to in-water (river bottom) sediment from fishing in the harbor.
- People want to know how much contact with the river is safe, and how much contact constitutes a health risk.
    - This report specifically addresses this concern.
- People have indicated a need for signs warning the community which areas and activities are unsafe.
    - Based on available data, EHAP has identified the beach at the former GASCO site as a place where warning signs would be appropriate. EHAP will work with DEQ and EPA to ensure that warning signs are

designed and posted in appropriate locations notifying visitors of the hazard.
    - EHAP is working to determine how fish advisory signs will be maintained over the long term.
    - The City of Portland also maintains warning signs located at likely swimming access areas near CSOs.
- People want information on the pollutants in the river.
    - This report contains a comprehensive list of the contaminants measured in various media (beach sediment, in-water sediment, and surface water) and their concentrations.
- Community members are concerned about air quality (fumes/ air pollution) in and around the site, which are migrating into nearby neighborhoods.
    - Ambient air quality in the vicinity of Portland Harbor is an issue that is outside the scope of this document. This is because ambient air quality is a function of current/ongoing emissions from operational facilities (permitted point sources), cars and trucks, and area sources such as residential wood-burning. Most of these sources are located beyond the Portland Harbor Superfund Site boundaries, and none of them are part of the Superfund process at Portland Harbor. Therefore, general air quality was not assessed in this document.
    - Information about air quality in the Portland neighborhoods surrounding the Portland Harbor Superfund Site can be found on the Oregon Department of Environmental Quality's website at: http://www.deq.state.or.us/aqi/aqiStationsPortland.aspx.
    - Oregon Department of Environmental Quality is also addressing ambient air quality in the Portland Metro area in a systematic way through the Portland Air Toxics Solutions (PATS) program. Information about PATS is available from DEQ's website at: http://www.deq.state.or.us/aq/toxics/pats.htm.
- People are bothered by industrial noise at all hours of the day and night.
    - EHAP acknowledges this concern and affirms that exposure to excess noise can harm people's health. However, EHAP is unable to address this concern specifically or quantitatively in this report. The City of Portland does have a Noise Control Program, and information about this program is available online: http://www.portlandonline.com/bds/index.cfm?c=42438.
- Some people want to know the effects of dredging the river and how it will disperse/displace contaminants into the river water and onto the beaches.
    - Site clean-up is outside EHAP's expertise. EHAP respectfully defers these concerns to the EPA, as they are coordinating the clean-up of the Portland Harbor Superfund Site. EPA's activities at Portland Harbor are posted here: http://yosemite.epa.gov/R10/CLEANUP.NSF/sites/ptldharbor.
- People want to understand how they can influence the clean-up process.
    - The EPA is coordinating the clean-up process, so any input/comments regarding clean-up should be directed to the EPA. EHAP also

encourages interested parties to seek out and participate in regular meetings held by the Portland Harbor Community Advisory Group (CAG). Portland Harbor CAG information can be found at: http://www.portlandharborcag.info/

- Community members want to see the "polluter pays" concept enforced, and they want more companies to step forward to join the Lower Willamette Group (LWG).
    - EHAP acknowledges this concern and encourages community members to contact individual companies and the EPA, as the EPA is the regulatory/enforcement agency at the Portland Harbor Superfund Site. A list of potentially responsible parties can be found on the EPA website (see below).
- Community members want accessible, timely, and clear information about what's happening with the site.
    - EHAP strives to maintain transparency with the public and especially affected community members. Due to the complex nature of this site and the Public Health Assessment, this report took longer than anticipated to complete. EHAP apologizes for any inconvenience this delay has caused. For ongoing and current information on site updates, the Portland Harbor CAG web site can be found at: http://www.portlandharborcag.info/
    - EHAP maintains a publicly accessible webpage including updated information on the Portland Harbor Superfund Site. This site can be found at: www.healthoregon.org/ehap.
    - The EPA maintains a publicly accessible webpage on the Portland Harbor Superfund Site and the EPA's work there. This site can be found at: http://yosemite.epa.gov/R10/Cleanup.nsf/4ca19ed6a0fe79d588256ec90061cea7/75e7f27bd108f3eb88256f4a007ba018!OpenDocument.
- People want to know that field sampling and contaminant investigation work is of high quality, in order to support good clean-up decisions.
    - EHAP has confidence in EPA's data quality assurance process, and independently assesses whether data quality is adequate and sufficient to answer public health questions. EHAP is confident that the data from EPA's Round 2 Report were sufficient to support the analysis and conclusions presented here.

Conclusions

EHAP reached *three* important conclusions in this public health assessment.

People who regularly recreate (i.e., boat, swim, beach comb, etc.) at the former GASCO site beach over several years, may be exposed to polycylic aromatic hydrocarbons (PAH)s at levels that may increase their risk of developing cancer at some time in their lives. However, it is unlikely that this beach is presently being used recreationally on a regular basis. The PAH levels in the sediment at the beach located on the west bank of the Willamette River just south of river mile 6, also known as the former GASCO site, are high enough to elevate cancer risk to levels that are unacceptable for children and adults. This determination is based on assumptions that an adult or child visits this particular beach 94 days or more per year over the course of 30 or more years. It is unlikely that anyone is using the beach this often at the present time, but frequency could increase in the future if site conditions change.

Swallowing or touching chemical contaminants in water, beach sediment, and bottom sediment at other beaches is not expected to harm the health of people who recreate (i.e., boat, swim, beach comb, etc.) or work within the Portland Harbor Superfund Site. Based on sampling data available at the time this report is published, the concentrations of chemicals measured in water, beach sediment, and river bottom sediment (*except the beach mentioned in Conclusion 1*) are too low to harm the health of people (including children) who use the area for work or recreational purposes. The Oregon Department of Environmental Quality (DEQ) is continuing to collect environmental data at sites upland from the water's edge. EHAP will review the results and, if necessary, recommend future actions to safeguard public health.

Although not site-related, water contact of any kind near combined sewer overflow (CSO) areas during the rainy season could cause bacteria-related illness. Bacteria concentrations from sewage measured in the water around CSO areas following a rain storm could be high enough to cause bacteria-related illness in people who swallow small amounts of water while swimming or otherwise contacting water from the harbor. Call the City of Portland's Bureau of Environmental Services at 503-823-5328 for CSO locations. The CSO website is located at:
http://www.portlandonline.com/bes/index.cfm?c=31030

Recommendations

Based on EHAP's analysis of the available information about the Portland Harbor Superfund Site, EHAP has developed recommendations that, if followed, will protect the health of people who use the Portland Harbor Superfund Site.

EHAP recommends that the EPA and Responsible Parties:

- Continue efforts to clean-up sediments in the Portland Harbor Superfund Site that contribute to elevated chemical contaminant concentrations in fish.
- Clean up sediments at the beach most contaminated with PAHs.
- Within 1 year, install and maintain shore- and water-facing signs on the beach most contaminated with PAHs, the former GASCO site, warning of the potential health risk from recreating on or generally coming into contact with the sediment.

Community members and their families can protect their health and the health of their children if they will follow the recommendations below:

- Continue to observe fish advisories for Portland Harbor posted by the Oregon Public Health Division's Office of Environmental Public Health at www.healthoregon.org/fishadv.

- Avoid the beach most contaminated with PAHs, known as the former GASCO site, located on the west bank of the Willamette River just south of river mile 6 (see Figure 2 for location)
- Avoid swimming in or contacting the water from combined sewer overflow (CSO) areas
- To avoid bacteria-related illness, thoroughly wash hands before eating, after contacting water from Portland Harbor
- To avoid bacteria-related illness, thoroughly wash all body surfaces that come into contact with the water from Portland Harbor
- To avoid bacteria related illness, thoroughly wash any recreational equipment such as kayaks, oars, paddles, water skis, etc. after use at Portland Harbor

EHAP recommends that the City of Portland:

- Continue efforts to reduce the amount of sewage that spills into Portland Harbor from combined sewers
- Maintain signs marking CSO areas

Keep in mind that CSOs extend farther south than the actual Superfund Site study area. Other municipalities further down river may also have areas where sewage overflows into the Willamette River, which is not addressed in this PHA.

Public Health Action Plan

A Public Health Action Plan ensures that this Public Health Assessment identifies public health risks and provides a plan of action designed to reduce and prevent people's exposure to hazardous substances in the environment. This plan includes a description of actions that will be taken by EHAP, in collaboration with other agencies, to implement the recommendations outlined in this document.

Public health actions that have been taken:

- Public release of a previous Public Health Assessment that addressed the public health risks of eating resident fish from the Portland Harbor Superfund Site [1]
- Implementation of fish advisories to protect the public from chemical contaminants in resident fish
- Public outreach, including securing mini-grants for non-profit organizations promoting healthy fish choices and healthy methods of fish preparation
- Release of this Public Health Assessment for public comment on May 20, 2010
- Public release of summary fact sheet outlining the findings and recommendations from this report
- Incorporation of public comments into this Final Public Health Assessment

Public health actions that will be taken by EHAP in the future:

- Consult with DEQ and EPA about language and placement of signs at the most contaminated beach, known as the former GASCO site, in the Harbor where recreational use should be avoided until clean-up is complete.

- Within 1 year after the release of the final version of this document, EHAP will conduct a focused, follow-up assessment of the potential health risks from eating freshwater clams and mussels caught within the Portland Harbor Superfund Site Study Area.
- If future environmental data reveal potential health hazards not addressed in this report, EHAP will address them in separate assessments as the data become available.
- Present, discuss, and answer questions about the findings of this report in public meetings, public availability sessions, or other venues upon request within a month of its release.
- Remain available to agency partners such as DEQ and EPA as a consultative resource regarding human health impact and health education at the Portland Harbor Superfund Site.
- Remain available to community members to answer their questions and concerns about the public health impacts associated with use of the Portland Harbor Superfund Site.
- Remain available to the City of Portland Bureau of Environmental Services to consult regarding the design and placement of signs warning the public about swimming near CSOs.

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Appendix A. Response to Public Comments

This appendix describes how public comments were addressed and/or incorporated into this final draft of the Portland Harbor: Recreational Use Public Health Assessment. Comments were considered as anonymous, so no names or affiliations are listed with these comments. Similar comments were grouped together and paraphrased. Each comment is numbered, and EHAP's response follows in italics.

Comment 1: "Any beach that can be reached by boat from the river should be considered as recreational."

Response: EHAP agrees with this comment and has taken a new look at this. Because all beaches sampled are accessible by small boat from the river, EHAP combined all beach sampling data (industrial and recreational) and reclassified everything simply as "beaches." EHAP then applied recreational exposure factors to all beach sampling data. This created a substantial change in the assessment from the public comment version to this final version, including the addition of conclusion #1, identifying one particular beach, known as the former GASCO site, as a public health hazard to people who use it regularly over several years for recreational purposes.

Comment 2: "I often see ships with foreign flags in the Harbor with fishing lines out to catch fresh fish for foreign crews."

Response: While fish consumption is not the focus of this particular assessment, EHAP continues to try to get the word out about the existing fish advisory for the Harbor. EHAP is consulting with DEQ, EPA, Metro and the LWG about placing large fish advisory signs on some of the bridge pilings in the Harbor. This may help us communicate the advisory more effectively to foreign crews coming into the harbor on ocean-going vessels.

Comment 3: "While the PHA and human health risk assessment (HHRA) serve different purposes at the Superfund site, [we are] pleased that the documents are consistent in their approaches and findings. The PHA evaluated the same exposure pathways and exposed populations for direct contact with sediment and surface water as the HHRA. For the majority of exposure factors, the PHA used the same assumptions as the HHRA, including recommendations from EPA."

Response: Although true, EHAP's independent evaluation provides an important contribution to the overall site assessment

Comment 4: "The PHA concluded that 'swallowing or touching chemical contaminants in water, beach sediment, and bottom sediment are not expected to harm the health of people who recreate or work within the Portland Harbor Superfund Site,' which is consistent with the HHRA's conclusion that direct contact with sediment and surface water are not risk drivers at the site."

Response: In response to other public comments (comment 1) we altered our approach to assessing risk from beach sediment slightly. This approach has subsequently identified one specific beach in the harbor where very high PAH concentrations could increase cancer risk to unacceptable levels for people who recreate there regularly over the course of several years. However, we continue to conclude that for most people, eating resident fish is the main risk driver for the Portland Harbor Superfund Site.

Comment 5: "The PHA addresses bacterial contamination in the river as a health risk. The HHRA does not assess this type of risk, and we appreciate the PHA's unique role in this risk assessment conclusion."

Response: Thank you.

Comment 6: "As with the PHA, the HHRA concludes that eating resident fish is the main health risk from chemical contamination at the site."

Response: EHAP agrees that eating fish is the primary health risk from chemical contamination at the site for most people. In addition, we have identified one specific beach, the former GASCO site, where PAH contamination could elevate cancer risk to unacceptable levels for people who regularly contact sediment there over the course of several years. We hope this does not divert attention from the primary risk for most people, which is resident fish consumption.

Comment 7: "This public health assessment (PHA) is a thoughtful and well-reasoned examination of the recreational exposures and risks for the Portland Harbor Superfund Site. Throughout this PHA, the Environmental Health Assessment Program (EHAP) examined relevant exposure scenarios and routes, used a health-protective approach to screen potential contaminants of concern and made appropriate professional judgments based upon the available data. We would like to acknowledge the following aspects of this PHA that are particularly commendable and noteworthy: 1) the reiteration of fish consumption as the most likely exposure route presenting risks of adverse health outcomes, 2) the consideration of combined sewer overflow in Portland Harbor and corresponding risk of bacterial illness; 3) the assessment of no expected harm from swallowing or touching chemicals from water, beach or bottom sediment; 4) the choice of additional lifetime excess cancer risk that was deemed acceptable in the context of recreational exposures in Portland Harbor (i.e. 10^{-4}); 5)the acknowledgement of other more compelling issues and health risks for transient populations; 6) the exposure factors used to determine risk from contaminants found in sediment."

Response: Portland Harbor is a large and complex Superfund Site. EHAP appreciates this acknowledgment. We would like to note that the addition of the new Conclusion 1 in response to public comment in this final version has identified one beach where avid recreational users could have elevated cancer risk from direct exposure to sediment. Overall, our methods and choice of risk levels and exposure factors are all in accordance with ATSDR's methodology and guidance.

Comment 8: Page 2, Conclusion 1, ‘Next Steps.’ While some of the biomagnification of site-related contaminants can be explained by consumption of sediment dwelling creatures, one of the more problematic fish in Portland Harbor, the bass, is primarily a piscivore. We recommend changing the language to read, “…as it is primarily by feeding on lower trophic levels that chemical contaminant concentrations in fish become magnified.’”

Response: Your comment is acknowledged, however in our experience this is an uncommon term and may confuse the lay person reading this report. A more common term is eating lower on the food chain, which is what a bass is doing when it eats sediment dwelling creatures. Therefore we have altered the language but not exactly as recommended.

Comment 9: “Page 19, Table 8. Cancer risk is calculated for children 1-6 years old, using a 70-year exposure duration. It was unclear to us how this was estimated and whether exposure factors, such as body weight, were scaled over time.”

Response: EHAP found this comment very helpful as scaling of bodyweight over time in the cancer dose calculation had not been considered. In this final draft of the PHA, EHAP used the age-adjustment intake factors presented in EPA’s Risk Assessment Guidance for Superfund (RAGS) part B to calculate cumulative cancer doses for the first 30 years of life. For carcinogenic PAHs, EHAP used the additional adjustment factors as presented in the EPA guidance to account for the greater susceptibility to mutagenic carcinogens during the early years of life. Appendix D describes this methodology in detail as well as the assumptions made. EHAP feels that incorporating this methodology into the cancer risk assessment has increased the protectiveness of the assessment and that the assessment is more complete because of it. Thank you for this comment.

Comment 10: “Page 32, Recommendations: It is unclear why EHAP recommends that community members and families thoroughly wash all body surfaces that come into contact with water after swimming or touching water from Portland Harbor, as well as washing any recreational equipment after use in Portland Harbor. Was this recommendation for bacteria-related illnesses? If so, this should be clearly stated in the recommendation so that these recommendations are not used out-of-context for characterizing chemical risks in Portland Harbor.”

Response: Indeed, these recommendations are intended to reduce the risk of developing bacteria-related illness following contact with Portland Harbor water. This has been clarified in the language of these recommendations both in the summary page at the front of the PHA and in the Recommendations section at the end.

Appendix B. Comparison Values and Contaminant Screening

This appendix defines the various comparison values (CVs) that were used in this Public Health Assessment and describes the hierarchy by which they were chosen. This process is also explained in Chapter 7 of ATSDR's Public Health Assessment Guidance Manual [7]. Appendix B also explains the contaminant screening process.

CVs used in this document are listed below:

Environmental Media Evaluation Guides (EMEGs)
EMEGs are an estimate of contaminant concentrations low enough that ATSDR would not expect people to have a negative, non-cancerous health effect. EMEGs are based on ATSDR Minimal Risk Levels (MRLs, described below) and conservative assumptions about the public's contact with contaminated media, such as how much, how often, and for how long someone may be in contact with the contaminated media. EMEGs also account for body weight. For residential beach sediment and surface water, EHAP used EMEGs for children. For in-water sediment and industrial beaches, EHAP used adult EMEGs because children are not likely to contact these media.

Cancer Risk Evaluation Guides (CREGs)
CREGs are an estimate of contaminant concentrations that are low enough that ATSDR would expect no more than one excess cancer case in a million (10^{-6}) persons exposed during their lifetime (70 years). ATSDR's CREGs are calculated from EPA's "cancer slope factors" (CSFs) used for oral exposures (swallowing a contaminant). For inhalation exposures (breathing in a contaminant), ATSDR uses EPA's "unit risk values". These values are based on EPA evaluations and assumptions about hypothetical cancer risks at low levels of exposure.

Reference Dose Media Evaluation Guides (RMEGs)
ATSDR derives RMEGs from EPA's oral reference doses, which are developed based on EPA evaluations. RMEGs represent chemical concentrations in water or soil at which daily human contact is not likely to cause negative, non-cancerous health effects. For residential beach sediment and surface water, EHAP used RMEGs for children. For in-water sediment and industrial beaches, EHAP used adult RMEGs because children are not likely to contact these media.

Minimal Risk Levels (MRLs)
An MRL is an estimate of daily human exposure – by a specified route and length of time -- to a dose of a chemical that is likely to be without a measurable risk of negative, noncancerous effects. MRLs are based on ATSDR evaluations. Acute MRLs are designed to evaluate exposures lasting 14 days or less. Intermediate MRLs are designed to evaluate exposures lasting from >14-364 days. Chronic MRLs are designed to evaluate exposures lasting for 1 year or longer. Oral exposures (swallowing the contaminant) are measured in milligrams per kilogram per day [mg/kg/day] and inhalation exposures (breathing the contaminant) are measured in parts per billion [ppb] or micrograms per cubic meter [$\mu g/m^3$].

Lifetime Health Advisory (LTHA)
A LTHA is derived by EPA, and is the concentration of a contaminant in water that a person could drink for their entire lifetime from childhood on without experiencing harmful health effects.

Maximum Contaminant Levels (MCL)
MCLs are derived by EPA as enforceable standards for municipal water systems. These standards are not strictly health-based but are set as close to the maximum contaminant level goals (MCLGs) (Health Goals) as is feasible and are based upon treatment technologies, costs (affordability) and other feasibility factors, such as the availability of analytical methods, treatment technology and costs for achieving various levels of removal.

Regional Screening Levels (RSLs)
RSLs are contaminant concentrations in soil, water, or air, below which any negative health effects would be unlikely. RSLs are derived by EPA's Region 3 Office using EPA's reference doses (RfDs) and Cancer Slope Factors (CSFs). This ensures that RSLs take into account both non-cancer and cancer risks. EHAP used residential RSLs for recreational beach sediment and surface water screening, but because children are not likely to contact industrial beach sediment or in-water sediment, EHAP used industrial RSLs to screen those media. RSLs are available online at: (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm)

Risk Based Concentrations (RBCs)
The Oregon Department of Environmental Quality (DEQ) uses risk-based concentrations (RBCs) to screen environmental contaminants in soil, water, and air. RBCs are typically based on EPA toxicity factors for carcinogens and non-carcinogens.

ATSDR uses the hierarchy shown in Figure B1 (Adapted from Figure 7-2 in ATSDR's Public Health Assessment Guidance Manual [7]) to choose CVs for screening purposes.

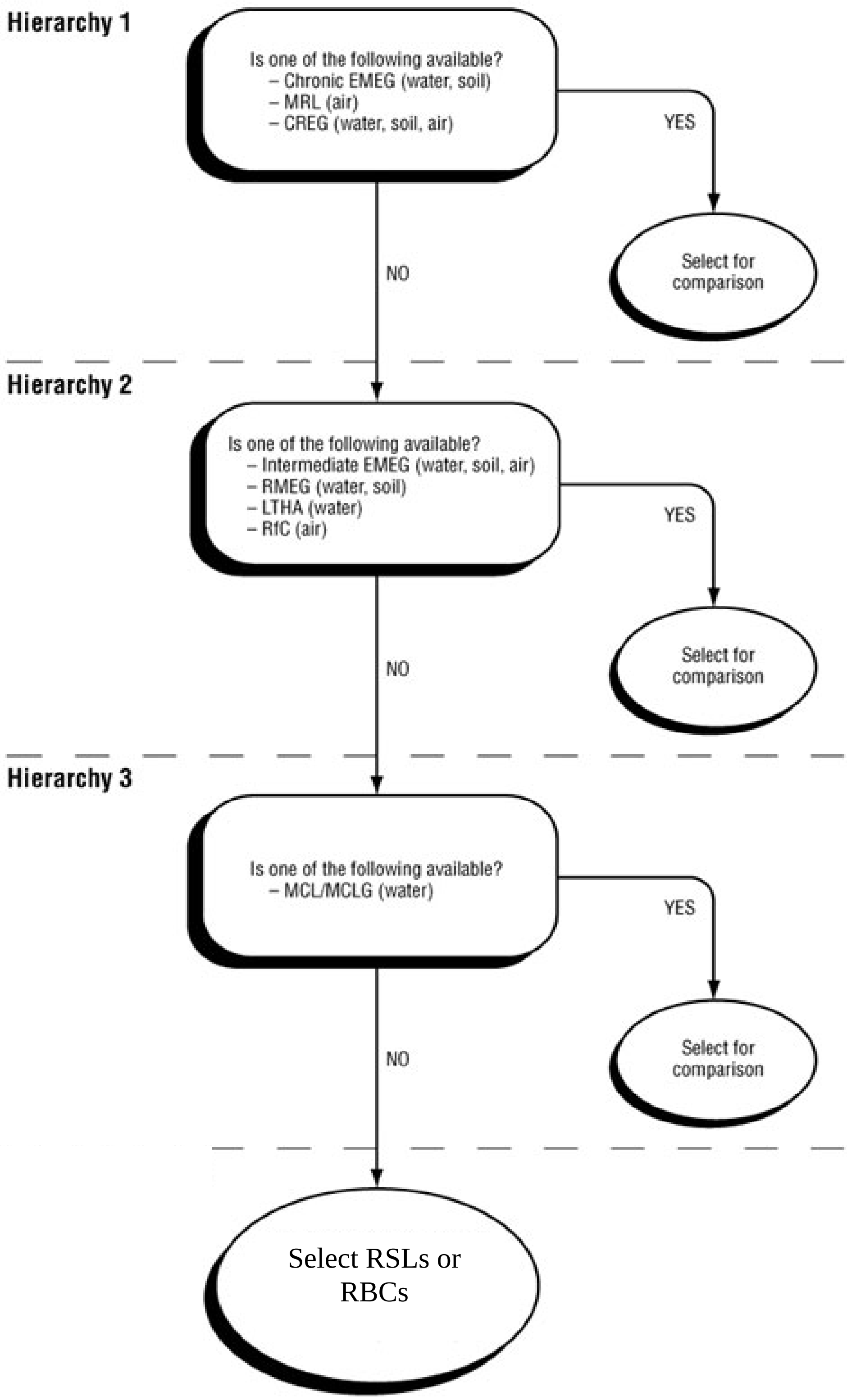

Figure B1. Environmental Guideline Hierarchy

In this Public Health Assessment, contaminants were screened by comparing the site-wide maximum contaminant concentration for each medium (beach sediment, in-water sediment, or surface water) against the best available Comparison Value (CV) according to the hierarchy described in Figure B1. Contaminant levels that were above their CV were labeled as contaminants of potential concern (COPC). A contaminant level above of its CV does not necessarily mean it is harmful to human health; rather it is a way for health assessors to identify and prioritize contaminants for the next phase of analysis.

Appendix C. Contaminant Screening

This appendix contains tables C1-C3 which show how contaminants measured in beach sediment, in-water sediment, and surface water at the Portland Harbor Superfund Site were screened against comparison values (CVs) for each contaminant in each medium. The CVs that EHAP used were provided by ATSDR and EPA according to the hierarchy shown in Figure B1 in Appendix B. This is according to the ATSDR Public Health Assessment Guidance Manual [7]. Appendix B describes ATSDR's CVs and their use.

Key for Table C1.
chr. = Chronic exposure is considered 1 year or longer.
int. = Intermediate exposure is considered one that lasts between 15-364 days.
mg/kg = milligrams of contaminant per kilogram soil; EMEG = Environmental Media Exposure Guide; RMEG = Reference Dose Media Evaluation Guide; RSL = Regional Screening Level; CREG = Cancer Risk Evaluation Guide; PCB = Polychlorinated biphenyl; TEQ = Toxic Equivalency Quotient; DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane
SVOC = Semi-volatile organic compounds; Y = Yes; N = No
Note: For beach sediment screening, EHAP chose EMEGs and RMEGs for children and RSL for residential soil.
Source data for this table came from reference [5].

Table C1. Portland Harbor Beach Sediment Contaminant Screening

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Metals				
Aluminum	22,100	50,000	chr. EMEG	N
Antimony	13	20	RMEG	N
Arsenic	9.9	20	chr. EMEG	N
Cadmium	0.73	5	chr. EMEG	N
Chromium	83.6	280	RSL	N
Copper	606	500	int. EMEG	Y
Lead	62	400	RSL	N
Mercury	0.18	23	RSL	N
Nickel	69	1,000	RMEG	N
Selenium	0.06	300	chr. EMEG	N
Silver	0.2	300	RMEG	N
Zinc	247	20,000	chr. EMEG	N
Polynuclear Aromatic Hydrocarbons				

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
2-Methylnaphthalene	2.2	2,000	chr. EMEG	N
Acenaphthene	3.6	3,000	RMEG	N
Acenaphthylene	5	3,000	RMEG*	N
Anthracene	8	20,000	RMEG	N
Benzo(a)anthracene	29	0.15	RSL	Y
Benzo(a)pyrene	41	0.1	CREG	Y
Benzo(b)fluoranthene	31	0.15	RSL	Y
Benzo(g,h,i)perylene	36	2,000	RMEG*	N
Benzo(k)fluoranthene	24	1.5	RSL	Y
Chrysene	38	15	RSL	Y
Dibenzo(a,h)anthracene	9.5	0.015	RSL	Y
Fluoranthene	68	2,000	RMEG	N
Fluorene	3.6	2,000	RMEG	N
Indeno(1,2,3-cd)pyrene	31	0.15	RSL	Y
Naphthalene	7	1,000	RMEG	N
Phenanthrene	47	2,000	RMEG*	N
Pyrene	80	2,000	RMEG	N
Phthalates				
Bis(2-ethylhexyl) phthalate	0.23	50	CREG	N
Dibutyl phthalate	0.19	5,000	RMEG	N
Diethyl phthalate	0.048	40,000	RMEG	N
SVOCs				
Carbazole	2.8	24	RSL 2004	N
Dibenzofuran	0.56	15	RSL 2004	N
Hexachlorobenzene	0.00066	0.4	CREG	N
Phenols				
4-Methylphenol	0.0095	310	RSL	N
Pentachlorophenol	0.022	6	CREG	N
Polychlorinated Biphenyls				
Total PCB Aroclors	1.57	0.4	CREG	Y
Total PCB Congeners	0.1	0.4	CREG	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Dioxin/Furan				
Total PCB TEQ	0.00003	0.00005	chr. EMEG	N
Total Dioxin TEQ	0.000001	0.00005	chr. EMEG	N
Pesticides				
alpha-Hexachlorocyclohexane	0.00048	0.1	CREG	N
beta-Hexachlorocyclohexane	0.0051	0.4	CREG	N
Endrin ketone	0.00046	18	RSL	N
Total Chlordanes	0.0059	2	CREG	N
Total DDD	0.13	3	CREG	N
Total DDE	0.1	2	CREG	N
Total DDT	0.14	2	CREG	N

*CV for surrogate compound

Key for Table C2.
Chr. = Chronic exposure is considered 1 year or longer.
Int. = Intermediate exposure is considered one that lasts between 15-364 days.
Mg/kg = milligrams of contaminant per kilogram soil; EMEG = Environmental Media Exposure Guide; RMEG = Reference Dose Media Evaluation Guide; RSL = Regional Screening Level; CREG = Cancer Risk Evaluation Guide; RBC = Oregon DEQ Risk-based concentration; PCB = Polychlorinated biphenyl; TEQ = Toxic Equivalency Quotient; DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane
SVOC = Semi-volatile organic compounds; VOCs = Volatile organic compounds; Y = Yes; N = No
Note: For in-water sediment screening, EHAP used adult EMEGs and RMEGs and RSL for industrial uses.
Source data for this table came from reference [5].

Table C2. In-Water Sediment Contaminant Screening

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Metals				
Aluminum	46,200	700,000	chr. EMEG	N
Antimony	32.1	300	RMEG	N
Arsenic	75.6	20	EMEG	Y
Barium	5,950	100,000	chr. EMEG	N
Beryllium	0.9	1,000	chr. EMEG	N
Cadmium	46.2	70	chr. EMEG	N
Chromium	774	1,400	RSL	N
Chromium hexavalent	2.1	700	chr. EMEG	N
Cobalt	23.9	7,000	int. EMEG	N
Copper	1,080	7,000	int. EMEG	N
Iron	64,500	720,000	RSL	N
Lead	1,950	800	RSL	Y
Manganese	2,130	40,000	RMEG	N
Mercury	2.5	28	RSL	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Nickel	594	10,000	RMEG	N
Selenium	20	4,000	chr. EMEG	N
Silver	14.8	4,000	RMEG	N
Thallium	27	66	RSL	N
Tin	5.4	200,000	int. EMEG	N
Titanium	3,450	100,000	RSL 2004	N
Vanadium	152	2,000	int. EMEG	N
Zinc	2,850	200,000	chr. EMEG	N
Butyltins				
Butyltin ion	0.74	200	chr. EMEG*	N
Dibutyltin dichloride	0.033	4,000	int. EMEG	N
Dibutyltin ion	2.7	200	chr. EMEG*	N
Monobutyltin trichloride	0.015	200	chr. EMEG*	N
Tetrabutyltin	1	200	chr. EMEG*	N
Tributyltin chloride	0.064	200	chr. EMEG*	N
Tributyltin ion	47	200	chr. EMEG*	N
Polynuclear Aromatic Hydrocarbons				
1,6,7-Trimethylnaphthalene	0.22	10,000	RMEG*	N
1-Methylnaphthalene	1.5	10,000	RMEG*	N
1-Methylphenanthrene	2.3	20,000	RMEG*	N
2,6-Dimethylnaphthalene	0.66	10,000	RMEG*	N
2-Methylnaphthalene	37.5	10,000	RMEG*	N
Acenaphthene	180	40,000	RMEG	N
Acenaphthylene	11	40,000	RMEG*	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Anthracene	160	200,000	RMEG	N
Benzo(a)anthracene	120	21	RSL	Y
Benzo(a)pyrene	140	0.1	CREG	Y
Benzo(b)fluoranthene	130	21	RSL	Y
Benzo(e)pyrene	36	20,000	RMEG*	N
Benzo(g,h,i)perylene	100	20,000	RMEG*	N
Benzo(k)fluoranthene	67.5	21	RSL	Y
Chrysene	140	210	RSL	N
Dibenzo(a,h)anthracene	14	0.21	RSL	Y
Fluoranthene	340	30,000	RMEG	N
Fluorene	110	30,000	RMEG	N
Indeno(1,2,3-cd)pyrene	100	2.1	RSL	Y
Naphthalene	100	10,000	RMEG	N
Phenanthrene	400	20,000	RMEG*	N
Pyrene	420	20,000	RMEG	N
Phthalates				
Bis(2-ethylhexyl) phthalate	440	50	CREG	Y
Butylbenzyl phthalate	2.8	100,000	RMEG	N
Dibutyl phthalate	3.8	70,000	RMEG	N
Diethyl phthalate	0.37	600,000	RMEG	N
Dimethyl phthalate	0.17	100,000	RSL 2004	N
Di-n-octyl phthalate	15.4	300,000	int. EMEG	N
SVOCs				
1,2,4-Trichlorobenzene	0.31	7,000	RMEG	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
1,2-Dichlorobenzene	0.61	200,000	chr. EMEG	N
1,3-Dichlorobenzene	0.098	10,000	int. EMEG	N
1,4-Dichlorobenzene	0.73	50,000	chr. EMEG	N
3-Nitroaniline	0.48	180	RSL	N
4-Chloroaniline	0.01	3,000	RMEG	N
4-Nitroaniline	0.096	1,800	RSL	N
Aniline	0.67	100	CREG	N
Benzoic acid	4.1	100,0000	RMEG	N
Benzyl alcohol	0.24	310,000	RSL	N
Bis(2-chloroethyl) ether	0.014	0.6	CREG	N
Carbazole	30	86	RSL 2004	N
Dibenzofuran	7.2	156	RSL 2004	N
Dibenzothiophene	7.5	156	RSL 2004*	N
Hexachlorobenzene	0.34	0.4	CREG	N
Hexachlorobutadiene	0.23	9	CREG	N
Hexachloroethane	1.5	50	CREG	N
N-Nitrosodiphenylamine	0.061	100	CREG	N
Perylene	14	20,000	RMEG*	N
Phenols				
2,3,4,5-Tetrachlorophenol	0.18	200,000	RMEG*	N
2,3,4,6;2,3,5,6-Tetrachlorophenol coelution	0.049	200,000	RMEG*	N
2,3,5,6-Tetrachlorophenol	0.028	200,000	RMEG*	N
2,4,5-Trichlorophenol	0.048	70,000	RMEG	N
2,4,6-Trichlorophenol	0.22	60	CREG	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
2,4-Dichlorophenol	0.12	2,000	RMEG	N
2,4-Dimethylphenol	0.3	10,000	RMEG	N
2-Chlorophenol	0.054	4,000	RMEG	N
2-Methylphenol	0.29	40,000	RMEG	N
4-Chloro-3-methylphenol	0.30	200,000	RMEG*	N
4-Methylphenol	1.4	3,100	RSL	N
Pentachlorophenol	8.4	6	CREG	Y
Phenol	0.68	200,000	RMEG	N
Polychlorinated Biphenyls				
Total PCB Aroclors	30.8	0.4	CREG	Y
Total PCB Congeners	35.4	0.4	CREG	Y
Total PCBs without dioxin-like congeners	35.0	0.4	CREG	Y
Dioxin/Furan				
Total Dioxin TEQ	0.017	0.0007	chr. EMEG	Y
Total PCB TEQ	0.00027	0.0007	chr. EMEG	N
Pesticides				
Aldrin	0.69	0.04	CREG	Y
alpha-Hexachlorocyclohexane	0.01	0.1	CREG	N
beta-Hexachlorocyclohexane	0.02	0.4	CREG	N
delta-Hexachlorocyclohexane	0.0053	0.4	CREG*	N
Dieldrin	0.36	0.04	CREG	Y
Diphenyl	0.67	40,000	RMEG	N
Endrin	0.03	200	chr. EMEG	N
Endrin aldehyde	0.0066	200	chr. EMEG*	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Endrin ketone	0.09	200	chr. EMEG*	N
gamma-Hexachlorocyclohexane	0.43	7	int. EMEG	N
Heptachlor	0.006	0.2	CREG	N
Heptachlor epoxide	0.017	0.08	CREG	N
Methoxychlor	0.034	4,000	RMEG	N
Mirex	0.05	0.096	RSL	N
Total Chlordanes	0.67	2	CREG	N
Total DDDs	3.0	3	CREG	Y
Total DDEs	2.5	2	CREG	Y
Total DDTs	12.5	2	CREG	Y
Total Endosulfans	0.27	1,000	chr. EMEG	N
Herbicides				
2,4,5-T	0.016	7,000	RMEG	N
2,4-D	3.3	7,000	RMEG	N
2,4-DB	0.34	6,000	RMEG	N
Dichloroprop	0.0094	7,000	RMEG*	N
MCPA	0.36	400	RMEG	N
MCPP	4.2	620	RSL	N
Silvex	0.0054	6,000	RMEG	N
VOCs				
1,1,1,2-Tetrachloroethane	0.00029	30	CREG	N
1,1-Dichloroethane	0.00031	17	RSL	N
1,2,3-Trichloropropane	0.00086	4,000	RMEG	N
1,2-Dichlorobenzene	0.61	200,000	chr. EMEG	N

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
1,2-Dichloroethane	0.00035	8	CREG	N
Acetone	0.16	600,000	RMEG	N
Benzene	0.089	10	CREG	N
Carbon disulfide	0.0045	70,000	RMEG	N
Chlorobenzene	16	10,000	RMEG	N
Chloroethane	0.02	62,000	RSL	N
Chloroform	0.098	7,000	chr. EMEG	N
cis-1,2-Dichloroethene	0.00027	200,000	int. EMEG	N
Dichlorodifluoromethane	0.029	100,000	RMEG	N
Ethylbenzene	0.47	70,000	RMEG	N
Isopropylbenzene	0.43	70,000	RMEG	N
Methyl isobutyl ketone	0.00033	52,000	RSL	N
Methyl n-butyl ketone	0.0018	52,000	RSL*	N
Methyl tert-butyl ether	0.00084	200,000	int. EMEG	N
Methylene chloride	0.0013	90	CREG	N
Methylethyl ketone	0.0098	400,000	RMEG	N
Styrene	0.0011	100,000	RMEG	N
Tetrachloroethene	0.00091	2.7	RSL	N
Toluene	0.052	10,000	int. EMEG	N
trans-1,2-Dichloroethene	0.00048	10,000	RMEG	N
Trichloroethene	0.00091	14	RSL	N
Vinyl chloride	0.00034	0.5	CREG	N
Total Xylenes	0.46	100,000	chr. EMEG	N
Petroleum				

Chemical	Maximum Detected (mg/kg)	Comparison Value (mg/kg)	Source of Comparison Value	Contaminant of Potential Concern?
Diesel Range Hydrocarbons	14,000	70,000	RBC	N
Gasoline Range Hydrocarbons	230	130,00	RBC	N
Lube Oil	9,420	70,000	RBC*	N
Motor oil	125	70,000	RBC*	N
Residual Range Hydrocarbons	18,000	70,000	RBC*	N
Conventionals				
Cyanide	5.4	10,000	RMEG	N
Perchlorate	269	500	chr. EMEG	N

*Comparison value for surrogate compound

Key for Table C3.
chr. = chronic exposure is considered 1 year or longer.
int. = intermediate exposure is considered one that lasts between 15-364 days.
µg/L = micrograms of contaminant per liter of water; EMEG = Environmental Media Exposure Guide; RMEG = Reference Dose Media Evaluation Guide; RSL = Regional Screening Level; CREG = Cancer Risk Evaluation Guide; RBC = Oregon DEQ Risk-based concentration; MCL = Maximum contaminant level; LTHA = Lifetime health advisory; PCB = Polychlorinated biphenyl; TEQ = Toxic Equivalency Quotient; DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane; 2,4-D = 2,4-dichlorophenoxyacetic acid
SVOC = Semi-volatile organic compounds; VOCs = Volatile organic compounds; Y = Yes; N = No
Note: For surface water screening, EHAP chose EMEGs and RMEGs for children and RSLs for residential drinking water.
Source data for this table came from reference [5].

Table C3. Portland Harbor Surface Water Contaminant Screening

Chemical	Maximum Detected (µg/L)	Comparison Value (µg/L)	Source of Comparison Value	Contaminant of Potential Concern?
Metals				
Aluminum	207	10,000	chr. EMEG	N
Antimony	0.06	4	RMEG	N
Arsenic	0.55	0.02	CREG	Y
Cadmium	0.03	1	chr. EMEG	N
Chromium	0.61	100	MCL	N
Copper	1.5	100	int. EMEG	N
Lead	0.28	15	MCL	N
Nickel	1.4	200	RMEG	N
Selenium	0.7	50	chr. EMEG	N
Silver	0.025	50	RMEG	N
Thallium	0.025	0.5	LTHA	N
Zinc	4.7	3,000	chr. EMEG	N
Butyltins				
Butyltin ion	0.002	3	chr. EMEG*	N

Chemical	Maximum Detected (µg/L)	Comparison Value (µg/L)	Source of Comparison Value	Contaminant of Potential Concern?
Dibutyltin ion	0.001	3	chr. EMEG*	N
Polynuclear Aromatic Hydrocarbons				
2-Methylnaphthalene	0.024	400	chr. EMEG	N
Acenaphthene	0.0046	600	RMEG	N
Acenaphthylene	0.0057	600	RMEG¥	N
Anthracene	0.002	3,000	RMEG	N
Benzo(a)anthracene	0.005	0.029	RSL	N
Benzo(a)pyrene	0.0012	0.005	CREG	N
Benzo(g,h,i)perylene	0.0012	300	RMEG*	N
Benzo(k)fluoranthene	0.0035	0.029	RSL	N
Chrysene	0.0042	2.9	RSL	N
Dibenzo(a,h)anthracene	0.0001	0.0029	RSL	N
Fluoranthene	0.02	400	RMEG	N
Fluorene	0.0031	400	RMEG	N
Indeno(1,2,3-cd)pyrene	0.0008	0.029	RSL	N
Naphthalene	0.035	200	RMEG	N
Phenanthrene	0.0073	300	RMEG*	N
Pyrene	0.0083	300	RMEG	N
Phthalates				
Bis(2-ethylhexyl) phthalate	0.023	3	CREG	N
Butylbenzyl phthalate	0.002	2,000	RMEG	N
Dibutyl phthalate	0.002	1,000	RMEG	N
Diethyl phthalate	0.0025	8,000	RMEG	N
SVOCs				

Chemical	Maximum Detected (µg/L)	Comparison Value (µg/L)	Source of Comparison Value	Contaminant of Potential Concern?
Hexachlorobenzene	0.000073	0.02	CREG	N
Hexachlorobutadiene	0.0000035	0.4	CREG	N
Phenols				
4-Chloro-3-methylphenol	0.075	50	RMEG*	N
Phenol	0.067	3,000	RMEG	N
Polychlorinated Biphenyls				
Total PCB Congeners	0.00061	0.02	CREG	N
PCBs without dioxin-like congeners	0.00059	0.02	CREG	N
Dioxin/Furan				
Dioxin TEQ	3.4E-07	0.00001	chr. EMEG	N
PCB TEQ	8.8E-09	0.00001	chr. EMEG	N
Pesticides				
Aldrin	0.0000027	0.002	CREG	N
alpha-Hexachlorocyclohexane	0.000082	0.006	CREG	N
beta-Hexachlorocyclohexane	0.0000094	0.02	CREG	N
Dieldrin	0.000043	0.002	CREG	N
Endrin	0.000001	3	chr. EMEG	N
Endrin ketone	0.0000008	3	chr. EMEG[b]	N
gamma-Hexachlorocyclohexane	0.00003	0.061	RSL	N
Heptachlor	0.00000027	0.008	CREG	N
Heptachlor epoxide	0.0000052	0.004	CREG	N
Methoxychlor	0.0000034	50	RMEG	N
Total Chlordanes	0.0013	0.1	CREG	N
Total DDDs	0.00051	0.1	CREG	N

Chemical	Maximum Detected (µg/L)	Comparison Value (µg/L)	Source of Comparison Value	Contaminant of Potential Concern?
Total DDEs	0.00051	0.1	CREG	N
Total DDTs	0.00051	0.1	CREG	N
Total Endosulfans	0.00077	20	chr. EMEG	N
Herbicides				
2,4-D	0.14	100	RMEG	N

*CV for surrogate compound

Appendix D. Exposure Assumptions and Dose Calculations

This appendix describes the formulas, methods, and assumptions used to calculate COPC doses for people in various exposure scenarios. The doses calculated here were used to calculate the risk for people exposed in these scenarios and to determine whether or not they might become ill because of contaminants at the Portland Harbor Superfund Site. For beach sediment and surface water, site-wide maximum concentrations of contaminants were used to calculate dose. This is very protective of human health, because people will likely be exposed to contaminants in various locations within the site boundaries, many of which have lower levels of contaminants than the maximum. For in-water sediment, an initial dose was calculated based on site-wide maximums, but then a more refined dose was calculated based on area-specific average concentrations for those COPCs that exceeded MRLs or cancer risk in excess of 1E-05 following the first round of calculation.

Non-Cancer dose calculation

Doses used for assessing risk of developing any illness other than cancer (non-cancer doses) were calculated as follows:

Total dose:

Total dose = $\text{Dose}_{sed} + \text{Dose}_{w}$

Where:
Dose_{sed} = Total dose from exposure to sediment
Dose_{w} = Total dose from exposure to surface water

And:
$\text{Dose}_{sed} = \text{Dose}_{os} + \text{Dose}_{ds}$

Where:
Dose_{os} = Oral dose from sediment
Dose_{ds} = Dermal dose from sediment

And:
$\text{Dose}_{w} = \text{Dose}_{ow} + \text{Dose}_{dw}$

Where:
Dose_{ow} = Oral dose from surface water
Dose_{dw} = Dermal dose from surface water

Terms in the next set of formulas are defined in Tables D1-D4.

$$\text{Dose}_{os} = \frac{C_{sed} \times IR_{sed} \times SCF^{*} \times CF_1 \times AF_o \times F \times ED}{AT_{nc} \times BW}$$

* Term used only in angler scenario for in-water sediment

$$Dose_{ds} = \frac{C_{sed} \times CF_1 \times SA \times SAF \times AF_{ds} \times SF^* \times F \times ED}{AT_{nc} \times BW}$$

* Term used only in angler scenario for in-water sediment

$$Dose_{ow} = \frac{C_w \times IR_w \times CF_2 \times CF_3 \times AF_o \times F \times ED}{AT_{nc} \times BW}$$

$$Dose_{dw} = \frac{C_w \times CF_3 \times CF_4 \times F \times ED \times t_{ev} \times SA \times K_p}{AT_{nc} \times BW}$$

Cancer dose calculation

Formulas for calculating cancer doses for **adult recreational users and anglers** are identical to those above except that that the averaging time (AT_{nc}) is replaced by the averaging time for cancer (AT_c) which is 25,550 days (365 days/year over a 70 year lifetime). This is common practice in cancer dose calculation because cancer results from the cumulative effect of multiple factors over an entire lifetime. Therefore, this calculation method incorporates the carcinogen dose from a particular source (the Portland Harbor Superfund Site in this case) over an entire lifetime.

Formulas for calculating cancer doses for child recreational users were more complex because body weights for children change over time and because of varying susceptibility to certain carcinogens over the course of childhood. Cancer risk to children was calculated as cumulative cancer risk for the first 30 years of life. Because body weights and other exposure factors change with age, EHAP used Age-Adjusted Intake Factors (IRAs) as shown in formulas below [16].

Total cancer dose (**for children**):

Total cancer dose = $Dose_{csed} + Dose_{cw}$

Where:

$Dose_{csed}$ = Total cancer dose from exposure to sediment

$Dose_{cw}$ = Total cancer dose from exposure to surface water

And:

$Dose_{csed} = Dose_{cos} + Dose_{cds}$

Where:

$Dose_{cos}$ = Oral cancer dose from sediment

$Dose_{cds}$ = Dermal cancer dose from sediment

And:

$$Dose_{cw} = Dose_{cow} + Dose_{cdw}$$

Where:

$Dose_{cow}$ = Oral cancer dose from surface water

$Dose_{cdw}$ = Dermal cancer dose from surface water

Terms in the next set of formulas are defined in Tables D1-D4.

$$Dose_{cos} = \frac{C_{sed} \text{ x } IRA_{sed\text{-}oral} \text{ x } CF_1 \text{ x } AF_o}{AT_c}$$

Where:

$$IRA_{sed\text{-}oral} = \frac{ED_{child(<6)} \text{ x } IR_{sed\text{-}child(<6)} \text{ x } F_{child(<6)}}{BW_{child(<6)}} + \frac{(ED_{adult} - ED_{child(<6)}) \text{ x } IR_{sed\text{-}adult} \text{ x } F_{adult}}{BW_{adult}}$$

$$Dose_{cds} = \frac{C_{sed} \text{ x } CF_1 \text{ x } IRA_{sed\text{-}dermal} \text{ x } AF_{ds}}{AT_c}$$

Where:

$$IRA_{sed\text{-}dermal} = \frac{ED_{child(<6)} \text{ x } SA_{child(<6)} \text{ x } SAF_{child(<6)} \text{ x } F_{child(<6)}}{BW_{child(<6)}} + \frac{(ED_{adult} - ED_{child(<6)}) \text{ x } SA_{adult} \text{ x } SAF_{adult} \text{ x } F_{adult}}{BW_{adult}}$$

$$Dose_{cow} = \frac{C_w \text{ x } IRA_{w\text{-}oral} \text{ x } CF_2 \text{ x } CF_3 \text{ x } AF_o}{AT_c}$$

Where:

$$IRA_{w\text{-}oral} = \frac{ED_{child(<6)} \text{ x } IR_{w\text{-}child(<6)} \text{ x } F_{child(<6)}}{BW_{child(<6)}} + \frac{(ED_{adult} - ED_{child(<6)}) \text{ x } IR_{w\text{-}adult} \text{ x } F_{adult}}{BW_{adult}}$$

$$Dose_{cdw} = \frac{C_w \text{ x } CF_3 \text{ x } CF_4 \text{ x } IRA_{w\text{-}dermal} \text{ x } K_p}{AT_c}$$

Where:

$$IRA_{w\text{-}dermal} = \frac{ED_{child(<6)} \text{ x } SA_{child(<6)} \text{ x } t_{ev\text{-}child(<6)} \text{ x } F_{child(<6)}}{BW_{child(<6)}} + \frac{(ED_{adult} - ED_{child(<6)}) \text{ x } SA_{adult} \text{ x } t_{ev\text{-}adult} \text{ x } F_{adult}}{BW_{adult}}$$

In the case of PAHs, which are believed to be mutagenic, cancer doses for children had to be further adapted to not only scale for body-weight over time but also to adjust for the fact that risk from exposures that occur in childhood are greater than risk from exposures that occur in adulthood [16]. To account for this the *IRAs for PAHs were modified as follows*:

IRA_{PAH} =

$$\frac{ED_2 \times IR_2 \times F_2 \times ADAF_2}{BW_2} + \frac{ED_6 \times IR_6 \times F_6 \times ADAF_6}{BW_6} + \frac{ED_{16} \times IR_{16} \times F_{16} \times ADAF_{16}}{BW_{16}} + \frac{(ED_{adult} - [ED_2 + ED_6 + ED_{16}]) \times IR_{adult} \times F_{adult}}{BW_{adult}}$$

Where:

- IRA_{PAH} – Age-adjusted Intake Rate for use with PAHs
- Subscript "2" refers to children 0 to <2 years old
- Subscript "6" refers to children 2 to <6 years old
- Subscript "16" refers to children 6 to <16 years old
- IR – Intake Rate – This term varies depending on exposure medium and exposure route as in the 4 IRA formulas described above.
- ADAF – Age-Dependent Adjustment Factor – This is a unitless adjustment factor designed to reflect the increased sensitivity of younger children to mutagenic carcinogens like PAHs.

<u>Exposure assumptions</u>

Tables D1-D4 describe in detail the assumptions and terms that were used in calculating contaminant doses for various exposure scenarios. Tables D1 and D2 define exposure assumptions for recreational users, while Tables D3 and D4 lay out the same information for the angler scenario.

Table D1. Sediment exposure factors for recreational users

Exposure Factor	Description	Value					Units	Rationale
		Adult	$Child_{<6}$	$Child_{<2}$	$Child_{2-<6}$	$Child_{6-<16}$		
C_{sed}	Concentration of contaminant in sediment	---	---	---	---	---	mg/kg	Chemical specific; Beach sediment for Adults and Children, In-water sediment for workers
IR_{sed}	Oral intake rate for sediment	100	200	200	200	100	mg/day	ATSDR default values
CF_1	Conversion factor 1	0.000001	0.000001	0.000001	0.000001	0.000001	kg/mg	Converts mg to kg
AF_o	Oral bioavailability factor	1	1	1	1	1	---	Assumes 100% absorption to be protective of health
F	Frequency	94	94	94	94	94	days/year	Professional judgment. For recreational users: 5 days/week during summer (13 weeks), 1 day/week during spring/fall (26 weeks), 1 day/month during winter (3 months)
ED	Exposure duration	30	6	2	4	10	years	**Adult and $Child_{<6}$**: ATSDR default values **$Child_{<2}$, $Child_{2-<6}$, and $Child_{6-<16}$**: Oregon DEQ [16]

Exposure Factor	Description	Value					Units	Rationale
		Adult	$Child_{<6}$	$Child_{<2}$	$Child_{2-<6}$	$Child_{6-<16}$		
AT_c	Averaging time, cancer	25550	25550	25550	25550	25550	days	ATSDR default value, based on 70 year lifetime
AT_{nc}	Averaging time, non-cancer	10950	2190	---	---	---	days	ATSDR default values, based on 30, and 6 year exposure durations
BW	Body weight	80	16	9	16	44.3	kg	**Adults**: ATSDR default value **Children**: EPA Child-specific exposure factors handbook (Table 8-1) [17]
SA	Exposed skin surface area	4656	3489	2225	3425	6675	cm^2	**Adults**: ATSDR default values (24% of adult male total surface area) **Children**: EPA child-specific exposure factors hand book (50% of total surface area) (Table 7-1) [17]
SAF	Sediment Adherence Factor	0.07	0.2	0.2	0.2	0.07	mg/day-cm^2	EPA guidance (Risk Assessment Guidance for Superfund [RAGS] Section E Appendix C) [18]

Exposure Factor	Description	Value					Units	Rationale
		Adult	$Child_{<6}$	$Child_{<2}$	$Child_{2-<6}$	$Child_{6-<16}$		
AF_{ds}	Dermal absorption factor for sediment	---	---	---	---	---	---	Chemical specific; See Table D5 for list of COPCs and their AF_{ds}
ADAF	Age-dependent adjustment factor	---	---	10	3	3	---	Oregon DEQ [16]

Notes:

Mg = Milligram
Kg = Kilogram
Cm = Centimeter
Cm^2 = square centimeter
ATSDR = Agency for Toxic Substances and Disease Registry
EPA = Environmental Protection Agency
DEQ = Department of Environmental Quality
COPC = Contaminant of Potential Concern

Table D2. Surface water exposure factors for recreational users

Exposure Factor	Description	Value					Units	Rationale
		Adult	$Child_{<6}$	$Child_{<2}$	$Child_{2\text{-}<6}$	$Child_{6\text{-}<16}$		
C_w	Concentration of contaminant in surface water	---	---	---	---	---	µg/L	Chemical specific
IR_w	Oral intake rate for surface water	50	50	50	50	50	mL/event	ATSDR Guidance
CF_2	Conversion factor 2	0.001	0.001	0.001	0.001	0.001	L/mL	Converts mL to L
CF_3	Conversion factor 3	0.001	0.001	0.001	0.001	0.001	mg/µg	Converts µg to mg
CF_4	Conversion factor 4	0.001	0.001	0.001	0.001	0.001	L/cm^3	Converts cm^3 to L (For dermal dose equation this conversion factor is used instead of CF_1)
AF_o	Oral bioavailability factor	1	1	1	1	1	---	Assumes 100% absorption to be protective of health
F	Frequency	26	65	65	65	65	events/year	Professional judgment. For recreational users: 2 days/week swimming during summer (13 weeks) for adults and 5 days/week swimming during summer (13 weeks) for children

Exposure Factor	Description	Value					Units	Rationale
		Adult	$Child_{<6}$	$Child_{<2}$	$Child_{2-<6}$	$Child_{6-<16}$		
ED	Exposure duration	30	6	2	4	10	years	**Adult and $Child_{<6}$**: ATSDR default values **$Child_{<2}$, $Child_{2-<6}$, and $Child_{6-<16}$**: Oregon DEQ [16]
AT_c	Averaging time, cancer	25550	25550	25550	25550	25550	days	ATSDR default value, based on 70 year lifetime
AT_{nc}	Averaging time, non-cancer	10950	2190	---	---	---	days	ATSDR default values, based on 30, and 6 year exposure durations
BW	Body weight	80	16	9	16	44.3	kg	**Adults**: ATSDR default value **Children**: EPA Child-specific exposure factors handbook (Table 8-1) [17]
SA	Exposed skin surface area	19400	6978	4450	6850	13350	cm^2	**Adults:** ATSDR default values for total body surface area **Children**: EPA child-specific exposure factors hand book total body surface (Table 7-1) [17]

Exposure Factor	Description	Value					Units	Rationale
		Adult	$Child_{<6}$	$Child_{<2}$	$Child_{2-<6}$	$Child_{6-<16}$		
K_p	Dermal permeability coefficient chemicals in water	---	---	---	---	---	cm/hour	Chemical specific; K_p values for each chemical shown in Table D6.
t_{ev}	Duration of swimming event	1	1	1	1	1	hour/event	Professional judgment
ADAF	Age-dependent adjustment factor	---	---	10	3	3	---	Oregon DEQ [16]

Notes:

Mg = Milligram
Kg = Kilogram
µg = microgram
mL = milliliter
L = liter
Cm = Centimeter
Cm^2 = square centimeter
Cm^3 = cubic centimeter
ATSDR = Agency for Toxic Substances and Disease Registry
EPA = Environmental Protection Agency
DEQ = Department of Environmental Quality

Table D3. In-water sediment exposure factors for anglers

Exposure Factor	Description	Value	Units	Rationale
C_{sed}	Concentration of contaminant in medium	---	mg/kg	Chemical specific
IR_{sed}	Oral intake rate for sediment	50	mg/day	Recommended by EPA Region 10
CF_1	Conversion factor 1	1E-06	kg/mg	Converts mg to kg
AF_o	Oral bioavailability factor	1	---	Assumes 100% absorption to be protective of health
F	Frequency	156	days/year	Professional judgment. 3 days/week for entire year
ED	Exposure duration	30	years	Recommended value for residential occupancy (EPA)
AT_c	Averaging time, cancer	25550	days	ATSDR default value, based on 70 year lifetime
AT_{nc}	Averaging time, non-cancer	10950	days	Based on 30 year exposure duration
BW	Body weight	80	kg	ATSDR default values
SCF	Sediment Contact Frequency	0.25	---	Recommended by EPA Region 10 – Assumes that anglers fish in cleaner areas 75% of the time
SA	Exposed skin surface area	1980	cm^2	ATSDR default for hands and forearms
SAF	Sediment Adherence Factor	0.328	mg/day-cm^2	EPA guidance (RAGS Section E Appendix C) [18]
AF_{ds}	Dermal absorption factor for sediment	---	---	Chemical specific (shown in Table D5)

Notes:

Mg = Milligram
Kg = Kilogram
Cm = Centimeter
Cm^2 = square centimeter
ATSDR = Agency for Toxic Substances and Disease Registry
EPA = Environmental Protection Agency

Table D4. Surface water exposure factors for anglers

Exposure Factor	Description	Value	Units	Rationale
C_w	Concentration of contaminant in medium	---	µg/L	Chemical specific
IR_w	Oral intake rate for surface water	25	mL/day	Professional judgment. Assumes accidental ingestion of water that gets on hands while fishing
CF_2	Conversion factor 2	0.001	L/mL	Converts mL to L
CF_3	Conversion factor 3	0.001	mg/µg	Converts µg/mg
CF_4	Conversion factor 4	0.001	L/cm^3	Converts cm^3 to L (For dermal dose equation this conversion factor is used instead of CF_1)
AF_o	Oral bioavailability factor	1	---	Assumes 100% absorption to be protective of health
F	Frequency	156	days/year	Professional judgment. 3 days/week for entire year
ED	Exposure duration	30	years	Recommended value for residential occupancy (EPA)
AT_c	Averaging time, cancer	25550	days	ATSDR default value, based on 70 year lifetime
AT_{nc}	Averaging time, non-cancer	10950	days	Based on 30 year exposure duration
BW	Body weight	70	kg	ATSDR default values
SA	Exposed skin surface area	1980	cm^2	ATSDR default for hands and forearms
K_p	Dermal permeability coefficient for chemicals in water	---	cm/hour	Chemical specific (Shown in Table D6)
t_{ev}	Duration of skin exposure to surface water during day of fishing	1	hour/day	Professional judgment

Notes:

Mg = Milligram
Kg = Kilogram
µg = microgram
mL = milliliter
L = liter
Cm = Centimeter
Cm^2 = square centimeter
Cm^3 = cubic centimeter
ATSDR = Agency for Toxic Substances and Disease Registry
EPA = Environmental Protection Agency

Table D5. AF_{ds} values for COPCs in beach and in-water sediment

COPC	AF_{ds}	Comment
Antimony	---	
Arsenic	0.03	Chemical-specific
Cadmium	0.001	Chemical-specific
Chromium	---	
Copper	---	
Iron	---	
Lead	---	
Thallium	---	
Tributyltin ion	---	
Benzo(a)anthracene	0.13	Chemical-specific
Benzo(a)pyrene	0.13	Chemical-specific
Benzo(b)fluoranthene	0.13	Chemical-specific
Benzo(k)fluoranthene	0.13	Chemical-specific
Chrysene	0.13	Chemical-specific
Dibenzo(a,h)anthracene	0.13	Chemical-specific
Indeno(1,2,3-cd)pyrene	0.13	Chemical-specific
Bis(2-ethylhexyl) phthalate	0.1	General for Semi Volatile Organic Compounds
Pentachlorophenol	0.25	Chemical-specific
Total PCB Aroclors	0.14	Chemical-specific
Total PCB Congeners	0.14	Chemical-specific
Total PCBs without dioxin-like congeners	0.14	Chemical-specific
Total Dioxin TEQ	0.03	Chemical-specific
Total PCB TEQ	0.03	Chemical-specific
Aldrin	0.1	General for Semi Volatile Organic Compounds
Dieldrin	0.1	General for Semi Volatile Organic Compounds
Mirex	0.1	General for Semi Volatile Organic Compounds
Total DDDs	0.03	Chemical-specific
Total DDEs	0.03	Chemical-specific
Total DDTs	0.03	Chemical-specific
Perchlorate	---	

COPC = contaminant of potential concern; AF_{ds} = Dermal absorption factor for sediment; TEQ = Toxic Equivalency Quotient; PCB = Polychlorinated biphenyl; DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane

"---" = No AF_{ds} for this chemical exists. For these chemicals, no dermal dose from sediment was calculated.

Table D6. K_p values for COPCs

COPC	K_p (cm/hr)
Antimony	0.001
Arsenic	0.001
Cadmium	0.001
Chromium	0.002
Copper	0.001
Lead	0.0001
Thallium	0.001
Benzo(a)anthracene	0.47
Benzo(a)pyrene	0.7
Benzo(k)fluoranthene	0.76
Chrysene	0.47
Dibenzo(a,h)anthracene	1.5
Indeno(1,2,3-cd)pyrene	1
Bis(2-ethylhexyl) phthalate	0.025
Total PCB Aroclors	0.75
Total PCB Congeners	0.75
Total PCBs without dioxin-like congeners	0.75
Total Dioxin TEQ	0.81
Total PCB TEQ	0.75
Aldrin	0.0014
Dieldrin	0.012
Total DDDs	0.18
Total DDEs	0.16
Total DDTs	0.27

Notes:
COPC = contaminant of potential concern; K_p = Dermal permeability coefficient for chemicals in water; Cm/hr = centimeters per hour; TEQ = Toxic Equivalency Quotient; PCB = Polychlorinated biphenyl; DDD = Dichlorodiphenyldichloroethane; DDE = Dichlorodiphenyldichloroethylene; DDT = Dichlorodiphenyltrichloroethane

Tables D7-D9 show how total doses were obtained by combining doses from sediment and surface water for the recreational user and angler scenarios. Only doses for non-cancer effects are shown here. Doses for cancer effects were calculated the same way, but the sediment and water components of the doses were calculated using the methodology described above for cancer dose calculation. Cancer risks are averaged over a lifetime of exposure, so the values are always lower than the doses for estimating non-cancer risks. Risk evaluation is described in the Public Health Implications subsection of the discussion in the main body of this report.

Table D7. Total dose to adult recreational users for COPCs identified

Chemical	Dose from Sediment (ng/kg/day)	+	Dose from Surface Water (ng/kg/day)	=	Total Dose (ng/kg/day)
Arsenic	3.5	+	0.034	=	3.5
Copper	195	+	0.09	=	195
Benzo(a)anthracene	13	+	0.041	=	13
Benzo(a)pyrene	19	+	0.014	=	19
Benzo(b)fluoranthene	14	+	---	=	14
Benzo(k)fluoranthene	11	+	0.046	=	11
Chrysene	17	+	0.034	=	17
Dibenzo(a,h)anthracene	4	+	0.0027	=	4
Indeno(1,2,3-cd)pyrene	14	+	0.014	=	14
Total PCB Aroclors	0.74	+	---	=	0.74

Note: All numbers shown here are rounded to two significant digits. Complete numbers were used in all calculations.
ng/kg/day = nanograms chemical per kilogram body weight per day
PCB = Polychlorinated biphenyl
“---“ = Contaminant not detected in surface water

Table D8. Total dose to children (0-6 years old) recreational users for COPCs

Chemical	Dose from Sediment (ng/kg/day)	+	Dose from Surface Water (ng/kg/day)	=	Total Dose (ng/kg/day)
Arsenic	35	+	0.35	=	36
Copper	1951	+	0.92	=	1952
Benzo(a)anthracene	136	+	0.19	=	136
Benzo(a)pyrene	192	+	0.64	=	192
Benzo(b)fluoranthene	145	+	---	=	145
Benzo(k)fluoranthene	112	+	0.21	=	113
Chrysene	178	+	0.15	=	178
Dibenzo(a,h)anthracene	44	+	0.012	=	44
Indeno(1,2,3-cd)pyrene	145	+	0.062	=	145
Total PCB Aroclors	8	+	---	=	8

Note: All numbers shown here are rounded to two significant digits. Complete numbers were used in all calculations.
ng/kg/day = nanograms chemical per kilogram body weight per day
PCB = Polychlorinated biphenyl
“---“ = Contaminant not detected in surface water

Table D9. Total dose to anglers for COPCs (based on site-wide maximum concentration for in-water sediment)

Chemical	Dose from Sediment (ng/kg/day)	+	Dose from Surface Water (ng/kg/day)	=	Total Dose (ng/kg/day)
Arsenic	7	+	0.79	=	7
Lead*	---		---		---
Benzo(a)anthracene	22	+	0.026	=	22
Benzo(a)pyrene	25	+	0.0089	=	25
Benzo(b)fluoranthene	23	+	---	=	23
Benzo(k)fluoranthene	12	+	0.028	=	12
Dibenzo(a,h)anthracene	3	+	0.0016	=	3
Indeno(1,2,3-cd)pyrene	18	+	0.0086	=	18
Bis(2-ethylhexyl) phthalate	68	+	0.0092	=	68
Pentachlorophenol	2	+	---	=	2
Total PCB Aroclors	6	+	---	=	6
Total PCB Congeners	7	+	0.0049	=	7
Total PCBs without dioxin-like congeners	7	+	0.0048	=	7
Total Dioxin TEQ	0.0015	+	0.0000029	=	0.0015
Aldrin	0.11	+	0.00000041	=	0.11
Dieldrin	0.055	+	0.000011	=	0.055
Total DDDs	0.28	+	0.001	=	0.28
Total DDEs	0.23	+	0.00093	=	0.24
Total DDTs	1	+	0.0015	=	1

Note: All numbers shown here are rounded to two significant digits. Complete numbers were used in all calculations.
ng/kg/day = nanograms chemical per kilogram body weight per day
PCB = Polychlorinated biphenyl
TEQ = Toxic equivalency quotient
DDD = Dichlorodiphenyldichloroethane
DDE = Dichlorodiphenyldichloroethylene
DDT = Dichlorodiphenyltrichloroethane
"---" = Contaminant not detected in surface water
*See Appendix E for lead assessment

Appendix E. Dose and Health Risk Calculation for the Heavy Metal, Lead

The heavy metal, lead (Pb), was one of the COPCs identified for anglers exposed to in-water sediment while fishing. Because scientists, including toxicologists, chemists, and medical doctors, have been studying Pb for so long, there is sufficient information to calculate blood Pb concentrations (PbB) in micrograms per deciliter (µg/dL) based on concentrations in various media. The process described here estimates the total PbB from all sources in the environment and not only from the Portland Harbor Superfund Site. EHAP used site-specific information about exposure and Pb concentrations where known. For non-site-specific exposure scenarios, defaults established by EPA and approved by ATSDR were used. EHAP used 5 µg/dL PbB as the threshold for adverse health effects in adults (assuming that only adults would come into contact with in-water sediment from Portland Harbor).

The basic formula used to calculate PbB at the Portland Harbor Superfund Site is:

$$PbB = \delta_S TPb_{sed} + \delta_S TPb_S + \delta_D TPb_D + \delta_W TPb_W + \delta_{AO} TPb_{AO} + \delta_{AI} TPb_{AI} + \delta_F TPb_F$$

Where:

δ = Media specific slope factor. This term is used to estimate how Pb concentration in each media translates into PbB in µg/dL.

T = Relative time spent in contact with each media. Table D1 shows the assumptions used for this term for each medium.

Pb = Concentration of Pb in each medium.

Table E1 shows the meanings of terms in the above formula, the range of estimated PbB from each media, and overall PbB for anglers using the Portland Harbor Superfund Site. References indicated in the footnotes can be found in the References section of this document.

Table E1. Blood Lead Levels for anglers at the Portland Harbor Superfund Site

$PbB=\delta_S TPb_{sed} + \delta_S TPb_s + \delta_D TPb_D + \delta_W TPb_W + \delta_{AO} TPb_{AO} + \delta_{AI} TPb_{AI} + \delta_F TPb_F$					Slope Factor (δ)[c]		Blood Lead (µg/dL)	
Media	Term in Formula	Concentration (Pb)	Units	Relative Time Spent (T)	Low	High	Low[d]	High[e]
Outdoor Air	AO	0.0071[f]	µg/m³	0.14[g]	1.8	2.7	0.0017	0.0027
Indoor air	AI	0.0021[h]	µg/m³	0.86[i]	1.8	2.7	0.0032	0.005
Food	F	5[j]	µg/day	1	0.014	0.034	0.07	0.17
Water	W	4[j]	µg/L	1[k]	0.03	0.06	0.12	0.24
In-water sediment (site-wide maximum)	sed	2000[l]	mg/kg	0.035[m]	0.001	0.003	0.07	0.21
Soil from off-site	S	70[j]	mg/kg	0.97[n]	0.001	0.003	0.068	0.2
Dust	D	70[j]	mg/kg	1	0.0021	0.0096	0.15	0.67
Total	---	---	---	---	---	---	**0.48**	**1.5**

Note:
µg = micrograms; m^3 = cubic meters; kg = kilograms; L = liter; Pb = lead

The total estimated PbB (1.5 µg/dL) is 16.7 times lower than the 25 µg/dL action level for adults established by the Centers for Disease Control and Prevention (CDC). Some studies have shown that Pb can harm health in adults and children at levels much lower than the CDC's 25 µg/dL action level [19]. Fortunately, even using worst-case exposure assumptions, the estimated PbB is not significantly different than the national average

[c] Slope Factors for adults (because only adults contact in-water sediment) from 19. ATSDR, *Toxicological Profile for Lead*, D.o.H.a.H. Services, Editor. 2007: Atlanta, GA.
[d] Calculated using low slope factor
[e] Calculated using high slope factor
[f] Six year average ambient air Pb concentration measured at National Ambient Air Quality stations within 2 miles of the site (See Table E2)
[g] 8 hours a day for 156 days a year spent fishing at the Portland Harbor Superfund Site divided by 24 hours a day for 365 days in a year (1248 hrs/8760 hrs = 0.14)
[h] EPA recommends using 30 percent of outdoor air concentration for indoor air
[i] Any time not spent out on the Portland Harbor Superfund Site fishing (1-0.14 = 0.86)
[j] 19. ATSDR, *Toxicological Profile for Lead*, D.o.H.a.H. Services, Editor. 2007: Atlanta, GA.
[k] Assumes tap water, not site-specific surface water. EHAP chose this value because the default Pb concentration in tap water was higher than the average concentration of lead in surface water at the site. Using the default tap water value is more protective of health.
[l] Site-wide maximum in-water sediment concentration measured in Round 2 Data Report for the Portland Harbor Superfund Site
[m] Twenty-five percent of the relative time spent fishing (0.25 x 0.14 = 0.035). EPA used best professional judgment to develop the relative time spent fishing in the segment of Portland Harbor being evaluated.
[n] Contact with soil from anywhere other than in-water sediment from the Portland Harbor Superfund Site (1-0.035 = 0.965)

PbB for adults in the United States (1.56 µg/dL) [20]. EHAP did not consider Pb in in-water sediment to be a significant health hazard to anglers or anyone else using the Portland Harbor Superfund Site.

Table E2. Air Concentrations from National Ambient Air Quality Monitoring Stations near the Portland Harbor Superfund Site for Lead (PM_{10})

Location	Distance from site (miles)	Annual Mean Concentration (µg/m³)	Year
N Roselawn Ave.	1.5	0.0058	2003
N Roselawn Ave.	1.5	0.0082	2004
N Roselawn Ave.	1.5	0.011	2005
N Roselawn Ave.	1.5	0.0066	2006
N Roselawn Ave.	1.5	0.0079	2007
N Roselawn Ave.	1.5	0.0052	2008
1706 NW 24th Ave.	1	0.0051	2006
Overall Mean		0.0071[o]	

Note:
µg/m³ = micrograms per cubic meter of air

[o] Used in Table E1 for outdoor air concentration of Pb

Appendix F. Detailed Health Information for Arsenic, Benzo(a)pyrene, and Total Dioxin TEQ

Arsenic

Arsenic is a naturally occurring element widely distributed in the earth's crust. In the environment, arsenic is combined with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds [21].

At high levels, inorganic arsenic can cause death. Exposure to lower levels for a long time can cause a discoloration of the skin and the appearance of small corns or warts. Several studies have shown that ingestion of inorganic arsenic can increase the risk of skin cancer and cancer in the liver, bladder, and lungs. Inhaling inorganic arsenic can increase a person's risk for lung cancer [21].

The concentrations of arsenic in sediments and surface water at the Portland Harbor Superfund Site are too low to harm people's health or to cause any of the health problems mentioned above. See the Public Health Implications section of the Discussion in this document for more details about arsenic at the Portland Harbor Superfund Site specifically.

Benzo(a)pyrene

Polycyclic aromatic hydrocarbons (PAHs), including benzo(a)pyrene, are a class of chemicals that occur naturally in coal, crude oil, and gasoline. PAHs also are created from the incomplete burning of coal, oil and gas, garbage, or tobacco. Many products contain PAHs including creosote wood preservatives, roofing tar, certain medicines, dyes, and pesticides [8].

PAHs enter the atmosphere from vehicle exhaust, emissions from residential and industrial furnaces, tobacco smoke, volcanoes, and forest fires. PAHs may attach to particles produced during emission and in the air. PAHs may contaminate surface water and groundwater [8].

According to the International Agency for Research on Cancer, the National Toxicology Program, and EPA, certain PAHs have been classified as definite, probable, or possible carcinogens (cancer-causing agents). Some people who have breathed or touched mixtures of PAHs for long periods have developed cancer. In laboratory animals, some PAHs have caused lung, stomach, or skin cancer [8].

The concentrations of PAHs, including benzo(a)pyrene, in sediments and surface water at the Portland Harbor Superfund Site are too low to harm people's health or to cause any of the health problems mentioned above. See the Public Health Implications section of the Discussion in this document for more details about benzo(a)pyrene at the Portland Harbor Superfund Site specifically.

Total Dioxin TEQ

Total dioxin TEQ (Toxic Equivalency Quotient) is a sum of the concentrations of several chemicals of similar structure adjusted for their relative toxicity to the most potent chemical in the class, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Dioxins, furans, and dioxin-like polychlorinated biphenyls (PCBs) are the abbreviated names for a family of chemicals that share a similar chemical structure and are included in the total dioxin TEQ. Most of these chemicals are not manufactured or produced intentionally but are created when other chemicals or products are made. These chemicals may be created during burning of forests or household trash; chlorine bleaching of pulp and paper; or manufacturing or processing of certain types of chemicals, such as pesticides. Most soil and water samples contain trace amounts of dioxins and furans [13].

The most well-known and well-studied chemical in the dioxin, furan, and dioxin-like PCBs family is 2,3,7,8-TCDD. The EPA and the International Agency for Research on Cancer have classified 2,3,7,8-TCDD as likely to cause cancer in people. People exposed to high levels of dioxin have developed a skin condition called chloracne. Liver injury also may occur after heavy prolonged exposures. More research is needed to determine the health effects on people of all chemicals in the dioxin, furan, and dioxin-like PCBs family, but some studies suggest effects on hormonal balance and immune responses [13].

The concentrations of chemicals that make up total dioxin TEQ in sediments and surface water at the Portland Harbor Superfund Site are too low to harm people's health or to cause any of the health problems mentioned above. See the Public Health Implications section of the Discussion in this document for more details about the total dioxin TEQ at the Portland Harbor Superfund Site specifically.

Appendix G. Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR serves the public by using the best science available to take responsive public health actions and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the EPA, which is the federal agency that develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used in this PHA when communicating with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-888-42-ATSDR (1-888-422-8737).

Absorption:	How a chemical enters a person's blood after the chemical has been swallowed, has come into contact with the skin, or has been breathed in.
Acute Exposure:	Contact with a chemical that happens once or only for a limited period of time. ATSDR defines acute exposures as those that might last up to 14 days.
ATSDR:	The **A**gency for **T**oxic **S**ubstances and **D**isease **R**egistry. ATSDR is a federal health agency in Atlanta, Georgia that deals with hazardous substance and waste site issues. ATSDR gives people information about harmful chemicals in their environment and tells people how to protect themselves from coming into contact with chemicals.
Background Level:	An average or expected amount of a chemical in a specific environment or amounts of chemicals that occur naturally in a specific environment.
Bioavailability:	See **Relative Bioavailability**.
Cancer:	A group of diseases which occur when cells in the body become abnormal and grow, or multiply out of control.
Carcinogen:	Any substance shown to cause tumors or cancer in experimental studies.
CERCLA:	See **C**omprehensive **E**nvironmental **R**esponse, **C**ompensation, and **L**iability **A**ct.
Chronic Exposure:	A contact with a substance or chemical that happens over a long period of time. ATSDR considers exposures of more than one year to be *chronic*.

Completed Exposure Pathway:	See **Exposure Pathway**.
Comparison Value: **(CVs)**	Concentrations of substances in air, water, food, and soil that are unlikely, upon exposure, to cause adverse health effects. Comparison values are used by health assessors to select which substances and environmental media (air, water, food and soil) need additional evaluation while health concerns or effects are investigated.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA):	**CERCLA** was put into place in 1980. It is also known as **Superfund**. This act concerns releases of hazardous substances into the environment, and the cleanup of these substances and hazardous waste sites. This act created ATSDR and gave it the responsibility to look into health issues related to hazardous waste sites.
Concern:	A belief or worry that chemicals in the environment might cause harm to people.
Concentration:	How much or the amount of a substance present in a certain amount of soil, water, air, or food.
Contaminant:	See **Environmental Contaminant**.
Dermal Contact:	A chemical getting onto your skin. (See **Route of Exposure**).
Dose:	The amount of a substance to which a person may be exposed, usually on a daily basis. Dose is often explained as “amount of substance(s) per body weight per day”.
Dose / Response:	The relationship between the amount of exposure (dose) and the change in body function or health that result.
Duration:	The amount of time (days, months, years) that a person is exposed to a chemical.
Environmental Contaminant:	A substance (chemical) that gets into a system (person, animal, or the environment) in amounts higher than the **Background Level**, or what would be expected.

Environmental Media:	Usually refers to the air, water, and soil in which chemicals of interest are found. Sometimes refers to the plants and animals that are eaten by humans. **Environmental Media** is the second part of an **Exposure Pathway**.
U.S. Environmental Protection Agency (EPA):	The federal agency that develops and enforces environmental laws to protect the environment and the public's health.
Epidemiology:	The study of the different factors that determine how often, in how many people, and in which people disease will occur.
Exposure:	Coming into contact with a chemical substance. (For the three ways people can come in contact with substances, see **Route of Exposure**.)
Exposure Assessment:	The process of finding the ways people come in contact with chemicals, how often and how long they come in contact with chemicals, and the amounts of chemicals with which they come in contact.
Exposure Pathway:	A description of the way that a chemical moves from its source (where it began) to where and how people can come into contact with (or get exposed to) the chemical. ATSDR defines an exposure pathway as having 5 parts: 1. Source of Contamination, 2. Environmental Media and Transport Mechanism, 3. Point of Exposure, 4. Route of Exposure, and 5. Receptor Population. When all 5 parts of an exposure pathway are present, it is called a **Completed Exposure Pathway**. Each of these 5 terms is defined in this Glossary.
Frequency:	How often a person is exposed to a chemical over time; for example, every day, once a week, or twice a month.
Hazardous Waste:	Substances that have been released or thrown away into the environment and under certain conditions, could be harmful to people who come into contact with them.
Health Effect:	ATSDR deals only with **Adverse Health Effects** (see definition in this Glossary).

Ingestion: Swallowing something, as in eating or drinking. It is a way a chemical can enter your body (See **Route of Exposure**).

Inhalation: Breathing. It is a way a chemical can enter your body (See **Route of Exposure**).

kg Kilogram or 1000 grams. Usually used here as part of the dose unit mg/kg/day meaning mg (contaminant)/kg (body weight)/day.

µg Microgram or 1 millionth of 1 gram. Usually used here as part of the concentration of contaminants in water (µg/Liter).

mg Milligram or 1 thousandth of 1 gram. Usually used here as in a concentration of contaminant in soil mg contaminant/kg soil or as in the dose unit mg/kg/day meaning mg (contaminant)/kg (body weight)/day.

MRL: **M**inimal **R**isk **L**evel. An estimate of daily human exposure – by a specified route and length of time -- to a dose of chemical that is likely to be without a measurable risk of adverse, noncancerous effects. An MRL should not be used to predict adverse health effects.

NPL: The **N**ational **P**riorities **L**ist (which is part of **Superfund**.). A list kept by the U.S. Environmental Protection Agency (EPA) of the most serious uncontrolled or abandoned hazardous waste sites in the country. An NPL site needs to be cleaned up or is being looked at to see if people can be exposed to chemicals from the site.

PHA: **P**ublic **H**ealth **A**ssessment. A report or document that looks at chemicals at a hazardous waste site and tells if people could be harmed from coming into contact with those chemicals. The PHA also tells if possible further public health actions are needed.

Point of Exposure: The place where someone can come into contact with a contaminated environmental medium (air, water, food or soil). Some examples include: the area of a playground that has contaminated dirt, a contaminated spring used for drinking water, or the backyard area where someone might breathe contaminated air.

Population: A group of people living in a certain area or the number of people in a certain area.

PRP: **P**otentially **R**esponsible **P**arty. A company, government, or person that is responsible for causing the pollution at a hazardous waste site. PRP's are expected to help pay for the clean up of a site.

Public Health Assessment(s): See **PHA**.

Reference Dose (RfD): An estimate, with safety factors (see **safety factor**) built in, of the daily, life-time exposure of human populations to a possible hazard that is not likely to cause harm to the person.

Relative Bioavailability: The amount of a compound that can be absorbed from a particular medium (such as soil) compared to the amount absorbed from a reference material (such as water). Expressed in percentage form.

Route of Exposure: The way a chemical can get into a person's body. There are three exposure routes:
– breathing (also called inhalation),
– eating or drinking (also called ingestion), and
– getting something on the skin (also called dermal contact).

Safety Factor: Also called **Uncertainty Factor**. When scientists don't have enough information to decide if an exposure will cause harm to people, they use "safety factors" and formulas in place of the information that is not known. These factors and formulas can help determine the amount of a chemical that is not likely to cause harm to people.

SARA: The **S**uperfund **A**mendments and **R**eauthorization **A**ct in 1986 amended CERCLA and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects resulting from chemical exposures at hazardous waste sites.

Source (of Contamination): The place where a chemical comes from, such as a landfill, pond, creek, incinerator, tank, or drum. Contaminant source is the first part of an **Exposure Pathway**.

Special Populations: People who may be more sensitive to chemical exposures because of certain factors such as age, a disease they already have, occupation, sex, or certain behaviors (like cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Statistics: A branch of the math process of collecting, looking at, and summarizing data or information.

Superfund Site: See **NPL**.

Toxic: Harmful. Any substance or chemical can be toxic at a certain dose (amount). The dose is what determines the potential harm of a chemical and whether it would cause someone to get sick.

Toxicology: The study of the harmful effects of chemicals on humans or animals.

Tumor: Abnormal growth of tissue or cells that have formed a lump or mass.

Uncertainty Factor: See **Safety Factor**.

Certification

The Oregon Health Authority prepared the Portland Harbor Recreational Use Public Health Assessment under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It was completed in accordance with approved methodology and procedures existing at the time that this public health assessment was initiated. Editorial review was completed by the Cooperative Agreement partner.

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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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