Public Health Assessment for

Evaluation of Metals in Shellfish, Sediment and Soil on or near Sandy and Red Beaches

FORMER TREADWELL MINE COMPLEX

SANDY AND RED BEACHES

(Public Comment)

DOUGLAS, ALASKA

EPA FACILITY ID: AKD981767387

April 10, 2024

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

Comment Period Ends:

July 12, 2024

THE ATSDR PUBLIC HEALTH ASSESSMENT

A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR 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 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. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has now been released for a 90-day public comment period. After the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared by:

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Acknowledgement

ATSDR would like to thank the Douglas Indian Association tribal council and tribal elders for sharing their traditional knowledge about harvesting and eating shellfish and other memories and observations related to the former Treadwell Mine Complex. These conversations helped ATSDR understand the intimate relationship of tribal members with the greater Juneau environment and its resources.

Acronyms and Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
ADEC	Alaska Department of Environmental Conservation
ADFG	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AHA	American Heart Association
AK	Alaska
BG	background
BLRV	blood lead reference value
CBJ	City and Borough of Juneau
CDC	Centers for Disease Control and Prevention
CDL	Capitol Disposal Landfill
CV	comparison value
CSF	cancer slope factor
DIA	Douglas Indian Association
DU	decision unit
EPC	exposure point concentration
FDA	Food and Drug Administration
HHS	Health and Human Services
HQ	hazard quotient
IEUBK	integrated exposure uptake biokinetic (model)
kg	kilogram
MLLW	mean lower low water
mg	milligram
MRL	minimal risk level
NOAEL	no observed adverse effects level
PHA	public health assessment
PHAST	public health assessment tool
PSP	paralytic shellfish poisoning
PST	paralytic shellfish toxin
ppm	parts per million
RDA	recommended dietary allowance
RME	reasonable maximum exposure
RSL	regional screening level
SEACC	Southeast Alaska Conservation Council
SEATOR	Southeast Alaska Tribal Ocean Research
TUL	tolerable upper intake level
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
95UCL	95^{th} upper confidence limit (of the mean)

Summary

The Agency for Toxic Substances and Disease Registry (ATSDR) received a petition from the Douglas Indian Association (DIA) in 2018. DIA's tribal members originate from the T'aaku Kwáan and A'akw Kwáan clans of the Tlingit Tribe which have inhabited the Anax Yaa Andagan Yé (Douglas) and Dzantik'i Héeni (Juneau) region since time immemorial [DIA 2017]. The petition requested that ATSDR assess possible health effects from contamination at Sandy Beach and other nearby beaches caused by historic gold mining at the mines of the Treadwell Mine Complex; mining at the Treadwell Mine Complex ended in 1922. ATSDR accepted the petition in May of 2019.

The Treadwell Mine Complex is south of the city of Douglas on the eastern side of Douglas Island, across Gastineau Channel less than five miles from Juneau, Alaska. The public can access the area just past the Douglas Harbor Marina and Mayflower Island. The site has traditional significance to tribal members as the former T'aaku Kwáan village was located adjacent to Sandy Beach. The Tribe expressed specific concern about metals contamination in traditional food (mainly shellfish) and the sand or sediment at Sandy Beach (and other nearby beaches). The former Treadwell Mine Complex is a public use area with trails in the upland areas that provide access to the beaches. Tribal members from the greater Juneau area visit the beach regularly, as does the public.

The beachfront of the mine complex is divided at the pond-like feature created by the 1917 cave-in below the Glory Hole open pit mine, which was the initial location of lode mining in the Treadwell area [CBJ 2010]. Sandy Beach is on the north side of the cave-in beach pond feature and is a wide flat beach with white sandy mine tailings easily accessible to tribal members and the public. Savikko Park, including a playground and ball fields, is located at the entrance into the area and adjacent to Sandy Beach. Sandy Beach is the most used beach area in the Juneau/Douglas area and used daily all year long. Red Beach is the beach located south of the cave-in beach pond feature and is only accessible from the upland trail system or at low tide.

ATSDR addressed the following questions in this document:

- Could eating shellfish such as crab, clams, cockles, or mussels contaminated from the site harm people's health? Are shellfish safe to eat as part of a traditional diet?
- Could touching or accidentally swallowing contaminated sand or sediment at Sandy Beach, Red Beach or Savikko Park harm people's health?
- Could touching contaminated soil or accidentally swallowing contaminated soil in the upland mine areas harm people's health? Are there enough data to assess exposures in upland areas?

ATSDR came to the following six conclusions:

1. **People who eat clams, mussels, cockles, or other bivalves from beaches in the Juneau area may experience paralytic shellfish poisoning (PSP). Butter clams are the shellfish species**

most consistently elevated with paralytic shellfish toxins (PSTs) in the Juneau area and are particularly hazardous. The risk of paralytic shellfish poisoning is a public health hazard.

Basis for conclusion: People who eat clams, cockles, mussels, or other bivalves from beaches that have not been recently tested and cleared for PSTs could have serious health problems, including temporary paralysis, inability to breathe, and death in severe cases. The presence of PSTs is a natural phenomenon that is not related to the mine, but it is included in this report due to the potential severity of health impact.

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2. **People that consume shellfish would ingest similar metal levels from site shellfish, grocery store shellfish, or shellfish collected from uncontaminated "background" locations. Two shellfish consumption scenarios resulted in additional metal exposure, that can be mitigated. Children exposed to copper from eating sea cucumbers on a traditional or once-a-month diet may experience temporary gastrointestinal symptoms. In the traditional diet, exposure to inorganic arsenic in clams from the site, grocery store, or an uncontaminated location poses a moderate concern for increased cancer risk.**

Basis for Conclusion: Copper levels in sea cucumbers were high enough to potentially cause acute gastrointestinal symptoms such as stomach pain, nausea, diarrhea or vomiting in children under the age of six, following a single 4-ounce meal. These effects would be temporary.

In a traditional food diet containing 51 clam meals per year for a lifetime, exposure to inorganic arsenic resulted in a moderate concern for increased cancer risk (7.9 extra cases per ten thousand people), which is similar to cancer risks posed if the clams are purchased from the grocery store or collected from an uncontaminated location (2.2 extra cases per ten thousand people). Risks are higher for consumption of softshell clams than for other clam species. Arsenic exposure can be reduced by removing the siphon from softshell clams prior to consumption. In general, shellfish are a healthy protein source in a balanced diet.

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3. **ATSDR cannot conclude whether site-related metals are present in Gastineau Channel sediments or crabs at levels that could harm people's health.**

Basis for Conclusion. ATSDR does not have enough information to make a conclusion. Metals levels in the sediment of Gastineau Channel below the low tide line off Sandy and Red beaches have not been well characterized. Insufficient numbers of Dungeness crab samples were collected to evaluate their safety as a food item. However, the limited data for metals in crab do not show a health hazard for human consumption.

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4. **ATSDR cannot conclude if the levels of contamination in the past were harmful to tribal members who lived in Indian Village at the southeast edge of Douglas Alaska, prior to its burning and destruction in 1962.**

Basis for Conclusion. We don't have enough information to conclude whether past site-related chemical contaminants in soil, sediment, drinking water or shellfish could harm people's health. Because contaminants from mining, including metals and cyanide, were not characterized in the environment during that era, we will never have the information to decide whether exposures from the mine may have harmed people's health.

5. **ATSDR cannot conclude whether metals or cyanide concentrated during mining operations in the upland area soils of the historical mine area can harm people recreating in the area. ATSDR cannot conclude if metals in deep beach sediment (more than three feet deep) are harmful to recreational miners who dig deep holes in tailings on the beach.**

   Basis for Conclusion. Surface soil has not been characterized in upland areas of mining operations, except in two tailing pile areas at the former Mexican Mine that have been capped and annually monitored. Sandy and Red Beach sediment has not been characterized below three feet deep.

6. **Touching or swallowing small amounts of metals in sand while walking, playing, recreating, or harvesting shellfish on Sandy or Red Beaches or Savikko Park is not expected to harm people.**

   Basis for Conclusion. ATSDR evaluated several reports for information on the levels of metals found in soil and sediment at Sandy and Red Beaches and at Savikko Park. ATSDR compared the metal levels in sediment to health-based comparison values for soil to determine whether they pose a potential health hazard to people who walk or play on the beaches. Metal levels in beach sediment or sand were similar to, or even lower than, metals levels in sediment from unimpacted background areas of southeast Alaska. The metals levels in sediment were below the health-based screening criteria, indicating that the sediments do not pose a health hazard.

Next Steps

The City and Borough of Juneau and the Douglas Indian Association should

- participate in a shellfish monitoring program and provide the public with current and easily available information about PST conditions at monitored beaches, and
- post warnings about Paralytic Shellfish Poisoning in areas that are often unsafe for shellfish harvesting and consumption.

The City and Borough of Juneau, the Historical Society, and/or the Alaska Department of Environmental Conservation should

- evaluate if the upland areas of the site have been sufficiently characterized to protect public health, particularly if plans to further develop the area as an historic park come to fruition,
- post signs advising people not to dig deep holes at the beach. Evaluate whether education activities should be conducted to inform recreational miners about the potential hazards associated with re-mining historical tailings at depths that have not been characterized (i.e., greater than 3 feet deep), and

- consider designing and implementing a plan to characterize metals contamination in Gastineau Channel sediment and crabs, in areas where tribal and community members most commonly harvest Dungeness crabs. This project would inform public safety. Crabs are mobile animals and metals in edible tissues may come from background, multiple historical mines, or other sources of contamination in the area.

How Tribal members and the public can protect their health.

Beaches where shellfish are collected commercially are highly regulated and routinely tested for PSTs. Consider buying shellfish from the grocery store.

If you collect and eat shellfish from non-commercial area beaches, you can take these actions to reduce your risk:

- Know there is always some degree of risk associated with eating shellfish. Watch for early symptoms of PSP after eating shellfish and get medical attention immediately if any symptoms develop (see PSP-Fact-Sheet.pdf (seator.org). If possible, save a sample of the suspected food item for PST testing (but label it unsafe to eat),
- Contact your local tribal government, and/or check the SEATOR website at Shellfish Advisories - SEATOR.org for the latest plankton and toxin results from your community's monitored beach,
- Avoid harvesting shellfish when PST levels are above Alaska's regulatory safety limit of 80 µg saxitoxin/g tissue. Shellfish toxins are often highly localized. Do not assume that your favorite beach is safe simply because a nearby one has been tested. Avoid harvesting butter clams, which commonly have PST levels above Alaska's regulatory safety limit, and
- Do not eat the internal organs from crabs and shrimp. Remove internal organs before cooking the meat.

Tribal members and the public can take these steps to reduce metal exposures:

- Enjoy moderate consumption of shellfish from the site, as part of a varied, balanced and healthy diet. Collect crab from many different locations and eat in moderate amounts as part of a varied, balanced, and healthy diet. Protect yourself from PSTs (see above).
- Avoid serving sea cucumbers to children under the age of six to avoid potential stomach upset from copper exposure. Or, feed your children only a very small serving of sea cucumber at a time (less than 2 ounces).
- Reduce exposure to inorganic arsenic by choosing softshell clams less often than other clam species, and/or removing the siphon from softshell clams before consumption. Softshell clams are also sometimes referred to as steamer clams, nannynose, sand gaper, or long-necked clam. They can contain higher amounts of toxic inorganic arsenic than other local clam species do.
- Recreational miners should be aware that mercury, cyanide, arsenic, and other metals may be concentrated in deep soil and sediment at the beach, which have not been characterized. As a precaution, wear gloves, a long-sleeved shirt, long pants, and sturdy enclosed shoes to minimize skin exposure to tailings. After handling beach sediment from deeper than three feet, wash your hands thoroughly before eating, drinking, or smoking. Remove soiled shoes and outer clothing before entering your car or home.

- Recreational users of upland areas of the historical mine should be aware that mercury, cyanide, arsenic, and other metals may be present in surface soil, which have not been characterized except near two tailing piles (which have been capped and are annually monitored; see Figure 6). Contamination may be present near old building foundations and mining equipment. If you play in the soil or touch historical mine debris, wash your hands thoroughly before eating, drinking, or smoking. Remove your shoes and wash dog's paws before entering your home, to avoid potentially tracking contaminated soil into your home.
- Tribal and community members should remove shoes and wash dog's feet after playing or walking on the beach, to minimize the tracking of site soil and sediments into the home.

Purpose

The Agency for Toxic Substances and Disease Registry (ATSDR) received a petition from the Douglas Indian Association in 2018 [DIA 2018]. The petition requested that ATSDR assess possible health effects from contamination at Sandy Beach and other nearby beaches caused by historic gold mining at the mines of the Treadwell Mine Complex that ended in 1922. The tribe expressed specific concern about metals contamination in traditional food (mainly shellfish) and the sand or sediment at Sandy Beach (and other nearby beaches) where mine tailings were deposited. ATSDR accepted the petition in May of 2019 and addressed the following questions in this document:

- Could eating shellfish such as crab, clams, cockles, or mussels contaminated from the site harm people's health? Are shellfish safe to eat as part of a traditional diet?
- Could touching or accidentally swallowing contaminated sand or sediment at Sandy Beach or Red Beach harm people's health?
- Could touching contaminated soil or accidentally swallowing contaminated soil in the upland mine areas harm people's health? Are there enough data to assess exposures to activities in these areas?

Background

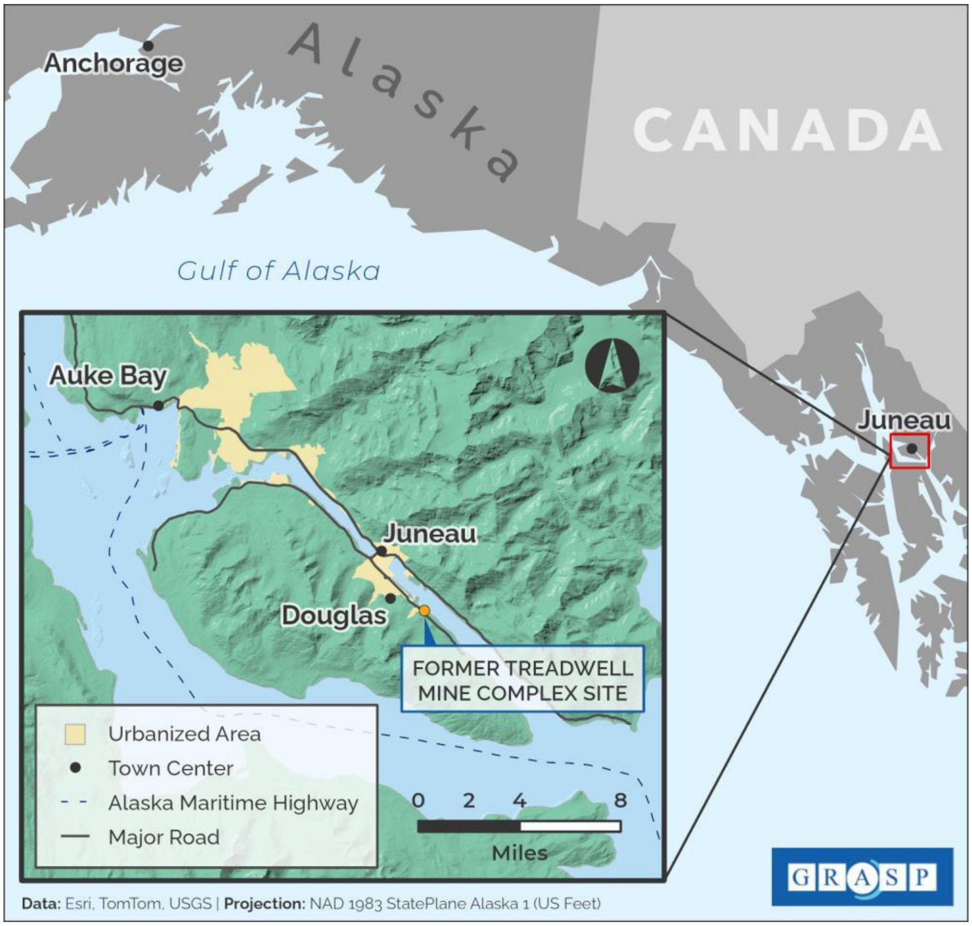
Site Description

The former Treadwell Mine Complex is south of the city of Douglas on the eastern side of Douglas Island, across Gastineau Channel less than four miles from Juneau, Alaska (Figure 1). The mine complex is just past the Douglas Harbor Marina and Mayflower Island and is a public use area with easy access to trails in the upland areas that provide access to the beaches (Figure 2). The beach front of the mine complex is divided at the pond-like feature created by the 1917 cave-in below the Glory Hole open pit mine. Sandy Beach is on the north side of the cave-in beach pond feature and is a wide flat beach with white sandy mine tailings. Red Beach is the beach located south of the cave-in beach pond feature and is only accessible from the upland trail system or at low tide.

Douglas Indian Association's Tribal members originate from the T'aaku Kwáan and A'akw Kwáan clans of the Tlingit Tribe, which have inhabited the Anax Yaa Andagan Yé (Douglas) and Dzantik'i Héeni (Juneau) region since time immemorial [DIA 2017]. The site has traditional significance to tribal members as the former T'aaku Kwáan village was located adjacent to Sandy Beach. Tribal members from all over the greater Juneau area visit the beach regularly, as does the public.

Savikko Park, including a playground and ball fields, is located at the entrance into the area and adjacent to Sandy Beach. Sandy Beach is the most used beach area in the Juneau/Douglas area and used daily all year long.

Figure 1. Location Map of the Former Treadwell Mine Complex and Douglas, Alaska



Former Mining Operations and Source of Contamination

Former mining operations placed tailings contaminated with chemicals into Gastineau Channel which formed Sandy and Red Beaches. From 1891 until 1917, four gold mines operated on the eastern side of Douglas Island along Gastineau Channel from south to north: Ready Bullion Mine, Mexican Mine, 700-Foot Mine, and Treadwell Mine [E&E 1991]. The first location of lode mining in the Treadwell area was an open pit mine called the "Glory Hole" [CBJ 2010]. The pit operated until 1906, when all workings in the pit ceased and the companies began to excavate the ore by tunneling deep within the ground [CBJ 2010]. The Glory Hole still exists today, but it is filled with water. Three of the mines closed following a large cave-in in 1917, while the Ready Bullion Mine closed permanently in 1922. Together, the four mines are known as the Treadwell Mine Complex (Figure 2).

Figure 2. Site Map of the Former Treadwell Mine Complex, Douglas, Alaska

Figure 3a. Treadwell Mine Complex from Mayflower Island, Douglas, Alaska [Alaska State Library, Paul Sincic Collection, ASL P75-420, ca 1896-1913, ASL-P75-420; permission granted on Alaska State Archives form signed 1/31/2023]

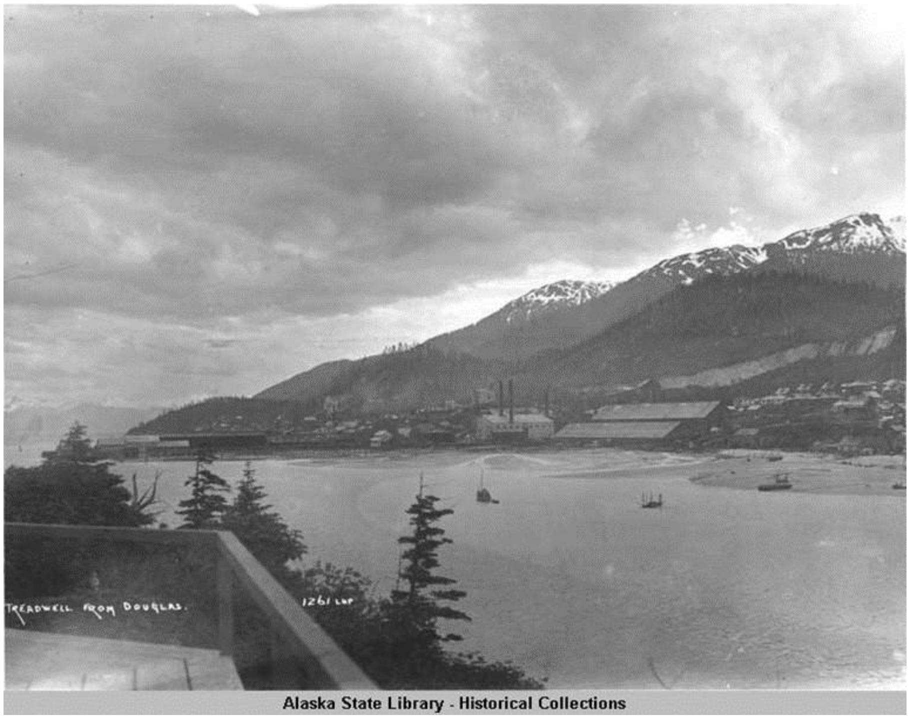


Figure 3b. Former Treadwell Mine Complex Area from Mayflower Island; same vantage point at low tide, Douglas, Alaska [Photo Credit: Bernadine DeAsis, DIA. May 2020; permission granted on CDC form signed 3/6/2023]

Gold-bearing ore (soil and rock) was removed from the ground by pit mining and underground tunneling. Miners pulverized gold-bearing rocks with stamp mills to the size of sand, then spread them over liquid mercury to remove gold. Cyanide was also used to remove gold from ore. Tailings are the sand-like material left over from the process of separating the gold from the ore. Tailings can contain other heavy metals. Collectively, the mines produced more than 20 million tons of ore during their operating years [E&E 1991].

On April 21, 1917, a sea-level cave-in occurred that flooded the underground tunnels of the Treadwell, 700-Foot, and Mexican mines. The three flooded mines were closed immediately. The Ready Bullion mine continued to operate, but it was unprofitable and closed permanently in 1922 [CBJ 2010].

Contamination from mining operations. The Treadwell Mine Complex produced two main types of waste: processed ore tailings and chemical wastes. Tailings from the mining operations, which may have contained mercury from processing and other metals concentrated from the ore, extend continuously north and south for about 8,000 feet, southeast from Sandy Beach to the Ready Bullion mine [Versar Inc. 1989]. The degree to which mine tailings may have entered Gastineau Channel, and the amount, nature, and extent of tailings that remain within the channel, is unknown.

Tailings from the cyanide mill are in two distinct areas at the Mexican Mine site: an "upper site" located about 500 feet inland from Gastineau Channel, and a "lower site" located about 4,000 feet southeast of Sandy Beach at tidewater [Versar Inc. 1989]. The upper site was capped with organic soil in 1996 to promote re-vegetation and re-contoured to divert surface drainage to the east [ADEC 2008; Smith Bayliss LeResche 2006]. The lower site was characterized in 2006, and a 15-inch gravel cap was completed in 2007 [Nortech 2007]. ADEC inspects both caps two times per year and AJT Properties, the mine owner, maintains them as necessary. They are in long-term monitoring status regulated by ADEC [ADEC 2020].

Mining contaminants may be found in areas around Sandy and Red beaches. These include the sand of the beaches, the sediment in Gastineau Channel wherever mine tailings were disposed of or have migrated and remain, and pore water in contact with contaminated sediment. Plants that grow in mine tailings, and animals that live in contaminated water or sediment, may uptake site contaminants. On this site the potential uptake of metals by local shellfish, and subsequent exposure to humans through shellfish consumption, is of particular concern.

Timeline

The major events affecting contamination and potential exposure pathways are below.

- **Pre-1890.** DIA territory encompasses the City and Borough of Juneau (CBJ) and surrounding areas. Tribal clans migrated up Taku River in summer to subsistence hunting/fishing camps. (The Taku River is still a destination for DIA Tribal members during the summer).
- **1911.** Approximately seven tons of elemental mercury were unaccounted for and presumed to be lost through spills and in ore tailings.

- **1917.** A major cave-in flooded the Treadwell, 700-Foot, and Mexican mines with seawater. The three mines closed immediately and permanently.
- **1922.** Mining operations at the Ready Bullion mine ceased. During the lifetime of the mine complex an estimated 70 tons of elemental mercury may have been lost.
- **1961.** The United States Army Corps of Engineers (USACE) planned and prepared specifications to develop Douglas Harbor, which was previously a part of Sandy Beach. The breakwater was completed, and the harbor was dredged in 1962.
- **1962.** The City of Douglas burned down Indian Village, displacing tribal residents.
- **1973.** The Alaskan Congress passed the Limited Entry Act, which reduced Tribal access to traditional foods. The greater Juneau area was later declared a non-subsistence use area.
- **1980s.** Elders reported that many DIA tribal members stopped harvesting shellfish from Sandy Beach and other Gastineau Channel locations because of concerns about contaminants and PSP.
- **1991.** ADEC commissioned a site inspection report of the former Treadwell Mine complex. Elevated levels of metals were found in several upland mill sites and tailings dumps, but not in a Sandy Beach composite sediment sample.
- **1991.** USFWS collected biota (fish, shrimp, blue mussels and/or cockles) and sediment from several areas in Gastineau Channel, including Sandy Beach. Heavy metal levels in Treadwell mine sediments, blue mussels, and cockles were similar to those found in other areas of SE Alaska.
- **1996**. ADNR capped and revegetated the upper cyanide tailings pile at the Mexican mine as part of a reclamation project.
- **1997.** USACE dredged the entrance channel to Douglas Harbor and disposed of the dredged material in the Gastineau channel [NewFields 2009].
- **2007.** AJT Mining Properties, Inc. capped the lower cyanide tailings pile at the Mexican Mine, in the Red Beach area.
- **2011.** DIA and ADEC collected five sediment samples from Sandy Beach and analyzed them for total mercury and arsenic. Further sampling was deemed warranted.
- **2012.** CBJ hired Nortech to characterize heavy metals in sediment from 11 decision units on Sandy beach and the intertidal zone using multi-incremental sampling methodology.
- **2014.** ADEC sampled the intertidal area of Sandy Beach and collected shellfish for heavy metals analysis.
- **2014 and 2016.** DIA and Ridolfi conducted two studies to evaluate arsenic and mercury in Sandy Beach sediment and shellfish. In both studies, arsenic and mercury were speciated to determine whether arsenic was organic or inorganic, and to determine how much of the mercury was in the methyl mercury form.
- **2015.** USACE contractor dredged Douglas Harbor and disposed of the dredged materials in Gastineau Channel. Sediment in the harbor and the channel disposal area contained methyl mercury, and both areas were capped with sand in 2016 [USACE 2017].
- **2018.** DIA petitioned ATSDR to evaluate heavy metals data in Sandy Beach shellfish and sediments.

Community and Tribal Population, Recreation, and Commerce

The site is located across Gastineau Channel from Juneau, the capital of Alaska. Two Tlingit Tribes have inhabited the area from time immemorial. Juneau is a major tourist destination and home to fishing fleets and miners. Next to the former mine area, the City and Borough of Juneau maintains a public park and Sandy Beach, a popular recreational destination.

Juneau and Douglas population. The U.S. Census Bureau estimates the population of Juneau City and Borough, Alaska to be 31,974 [U.S. Census 2019], 12% of whom are Alaska Native or American Indian. Figure 4 shows the area near the site and demographic information of the area's nearby population from the 2010 U.S. Census. There are approximately 6,000 Alaska Natives living in the greater area. DIA membership includes over 700 members, most of whom live within the City and Borough of Juneau [CBJ], which includes Douglas Island.

Commerce. The major industries in the area are tourism, fishing, and mining. Juneau is a major cruise line port. There are several commercially important fish and shellfish species in Southeast Alaska. Fisheries include king and coho salmon; halibut; crab (king, dungeness, tanner, golden and red king); and pandalid shrimp [ADFG 2021a]. Tribal and recreational shellfish and crabbing are discussed in more detail below.

Public Recreation at the Treadwell Mine Area. CBJ owns and maintains Sandy Beach and the adjacent Savikko Park. The Treadwell Mine Historic Trail Complex begins at the park and winds through the former mining area over approximately 35 acres. Residents and visitors use the beach, mining ruins, and network of trails day and night, summer, and winter. Recreation includes beachgoers, hikers, walkers, cyclists, dog walkers, joggers, and cross-country skiers [Tharp 2008]. There have been reports of people, including those experiencing homelessness, harvesting shellfish but not very often.

The playground targets toddlers and young children and is covered with sand from Sandy Beach. Tribal and community members use Sandy Beach recreationally (Figure 3b). They engage in hiking, dog walking and recreation. They also use the playground, pavilions, picnic tables and restrooms at Savikko Park. Sand from the beach blows into the park and tailings have mixed with sand originally brought into the park. CBJ estimated the number of people attending shelter rentals for the two years between July 2017 to July 2019 to be 23,391 [CBJ 2019, personal communication].

Douglas Indian Association. DIA's tribal members originate from the T'aaku Kwáan and A'akw Kwáan clans which have inhabited the Anax Yaa Andagan Yé (Douglas) and Dzantik'i Héeni (Juneau) region since time immemorial [DIA 2017]. The traditional and historical territory extended for miles (Figure 5). Among other Tlingit settlements, history records the establishment of a village in the 1880s on Yaa Andagan Yé (where the sunrays touch first) in the vicinity of Sandy Beach. Some village sites in the area had been inhabited for well over 750 years. They depend on the land, rivers, and sea for food.

During the years the mines were active, tribal members lived at the edge of Douglas right next to the mine; the locals called it Indian Village. There was no running water or electricity, and the houses were built on pilings. They found drinking water from a stream culvert and they used outhouses. Other tribal members lived in Juneau.

The DIA became a federally recognized Tlingit tribe in 1936 under the Alaska Native Reorganization Act, an amendment of the Indian Reorganization Act of 1934. According to tribal historians, the Indian Village was burned by the City of Douglas in the summer of 1962, when residents were at their subsistence camps at the Taku River. Having lost homes, fishing boats and nets, and personal possessions, tribal members dispersed throughout southeast Alaska.

Tribal access to traditional food. Tribal families had strong fishing livelihoods and practiced careful stewardship over resources offered by the land and sea. ATSDR heard several family histories of traditional fishing, hunting, and harvesting shellfish in the greater Juneau area, some of which may have occurred near the former Treadwell Mine Complex. The bridge across the channel to Douglas was first built in 1935, allowing easier access for residents and tribal members in Juneau to collect shellfish on the island. After 1962, tribal members were displaced around the greater Juneau area and southeast Alaska, decreasing proximity to the mine.

Several elders described going down to the beach to collect shellfish all along Gastineau Channel near what is now downtown Juneau, the north end of Douglas Island, north and south along the roads, and near the mines. They also mentioned going to different places by boat. One elder that recalls being a boy at the Indian Village said, "everyone used to go clamming and crabbing there [near the mine area]." He recalled collecting clams at the beach before the village burned, and that wintertime was for clamming and crabbing. He said there was another beach on the other side of the cave-in below the Glory Hole to collect shells from; there were huge snails in one area. Not all elders recall shell fishing near the mines, stating that there weren't enough shellfish to collect, or they were afraid of them being contaminated. Different elders reported getting different shellfish at different places and many stated that cockles and gumboots were their favorite. We heard about harvests of crab (dungeness, king, tanner), clams (butter, littleneck), cockles, and sometimes mussels, gumboots (lady slipper), black chiton, snails, sea urchin, or octopus.

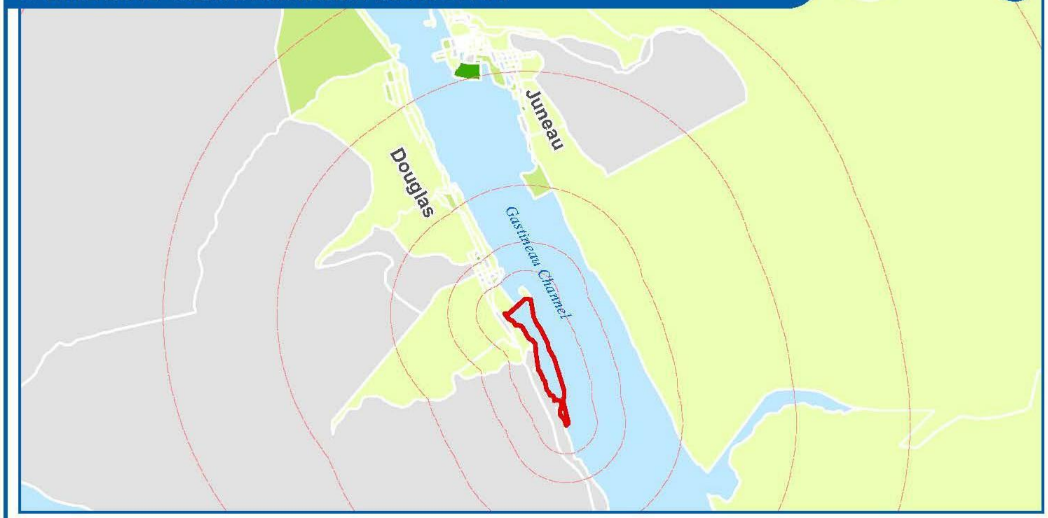
Figure 4. Demographics for the Juneau and Douglas Areas near the Former Treadwell Mine Complex, Alaska

Sandy Beach, Douglas, AK

City and Borough of Juneau

SENSITIVE POPULATION: AMERICAN INDIAN/ALASKA NATIVE & SITE AND DEMOGRAPHIC SNAPSHOT

INTRODUCTORY MAP SERIES



The **American Indian/Alaska Native Map** depicts the site of interest and the distribution and number of American Indian/Alaska Natives residing in the surrounding community. The distribution of population in and around a site is critical to understanding a community's potential for exposure to hazardous substances.

Based on US Census 2010 statistics, **1,059** American Indian/Alaska Natives reside within a **5-mile buffer** of the site of interest.

Site of Interest

- Site of Interest[1]
- Site of Interest Buffers[2]

Proportion of population that is AI/AN by Census Block[3]

- Zero
- 0.1% to 25%
- 25.1% to 50%
- 50.1% to 75%
- > 75%

0 0.5 1 2 3
Miles

AI/AN Population[3,4]
Within specified distance of site boundary

Distance	Total Pop	AI/AN	% AI/AN
0.25 mile	280	26	9.3%
0.50 mile	705	65	9.2%
1 mile	1,562	270	17.3%
3 miles	7,240	1,038	14.3%
5 miles	8,300	1,059	12.8%

Demographic Statistics[3,4]
Within 5 Miles buffer of site boundary

Measure	2000	2010	Change	Measure	2000	2010	Change
Total Population	8,332	8,300	+0%	Two or More Races	486	624	+28%
White Alone	6,370	6,083	-4%	Hispanic or Latino[6]	282	384	+36%
Black Alone	83	91	+9%	Children Aged 6 and Younger	595	621	+4%
Am. Indian & AK Native Alone	1,049	1,059	+0%	Adults Aged 65 and Older	812	945	+16%
Asian Alone	229	306	+33%	Females Aged 15 to 44	1,845	1,590	-13%
Native Hawaiian & Other Pacific Islander Alone	24	39	+62%	Housing Units	4,092	4,309	+5%
Some Other Race Alone	90	98	+8%	Housing Units Pre 1950	1,062	506	-52%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]US Census 2010.
Notes: [4]Calculated using area-proportion spatial analysis method.
Projection: NAD 1983 StatePlane Oklahoma North FIPS 3501 Feet.

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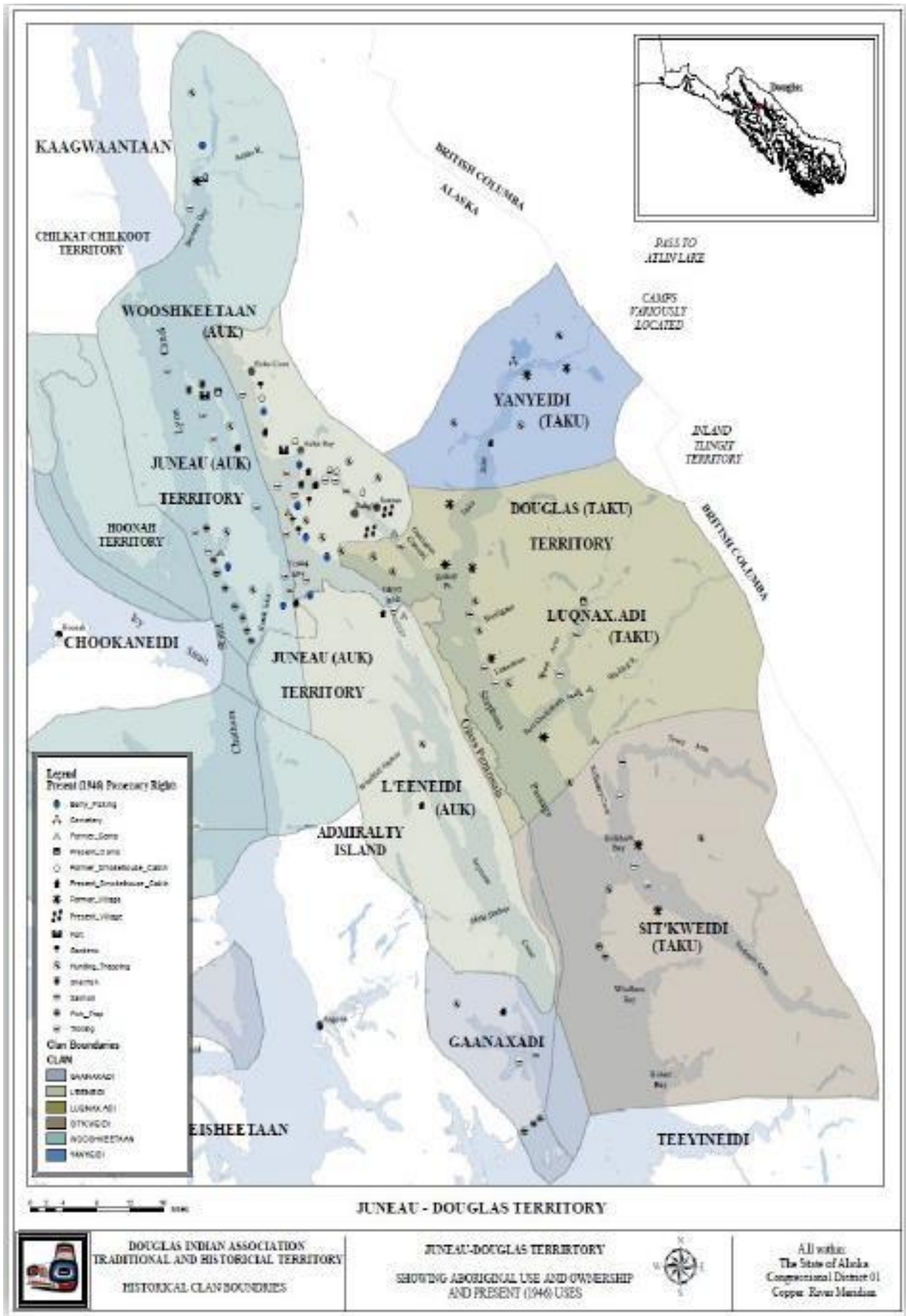
Figure 5. Map of the T'aaku Kwáan and A'akw Kwáan Traditional and Historical Territory (Source DIA 2017)



Some families fished for trade and bartered among other Alaska Natives as well as immigrants. Tribal fishing families passed down and received fishing boats and fishing and shell fishing gear. Fishers harvested salmon, halibut, dolly varden, herring, and other marine fish for miles around the area. Fishers leaving the Gastineau Channel dropped crab pots offshore, sometimes near the former Treadwell Mine Complex. One elder stated, "Sandy Beach is not a major collection area [for crab] and never has been. It is just an area of convenience." Plants and marine seaweed were also harvested in the greater Juneau area.

Alaska's Limited Entry Act decreased access to food. Prior to 1973, tribal elders described going to many areas to gather shellfish, either near Juneau, Douglas, or by boat. Shellfish hauls were and are shared among extended family. In 1973, the Alaska Legislature passed the Limited Entry Act to manage resources for the influx of commercial fishers. Although some Native families were awarded permits, others were denied. The State of Alaska activated a permit system during the Vietnam War when many tribal members were serving in the armed forces; hence, they missed their opportunity to be awarded a permit. One elder we interviewed stated, "when the permit system started, we began losing our fishing culture."

Fishing and shell fishing on Douglas Island (and Juneau) changed as tribal members could no longer just go down to the water to fish, look for gumboots and cockles, or catch crab. The Alaska Department of Fish and Game (ADFG) listed Juneau as a Non-Subsistence Use Area. The state defines Non-Subsistence Use Areas as places where dependence upon subsistence (customary and traditional uses of fish and wildlife) is not a principal characteristic of the economy, culture, and way of life [ADFG 2021b]. According to elders, Alaska Natives were not consulted in this decision.

Tribal Knowledge of History and Use of the Treadwell Mine Area. ATSDR met with several DIA elders and tribal members to listen and better understand their knowledge of the historical and current use of the site. As shown above in Figure 5, the area falls within their historical and traditional territory. A summary of these conversations is in Appendix A. Tribal members have been harvesting crab, clams, fish, and berries from areas at or near Sandy Beach for over 750 years. Traditionally, these resources have served as a means of supporting families with food in a subsistence manner.

Very few tribal members currently eat shellfish from the beach. More recently some of these activities are done to maintain traditional practices:

- Crab – Crab traps can be seen along Sandy and Red Beaches. Tribal members also recall harvesting for crab near Sheep Creek and the Taku River, both located across the Gastineau Channel from Douglas. ATSDR staff saw crab pots set off Sandy Beach in July 2019 and heard multiple tribal members, state, and city officials refer to the harvesting of crabs offshore from the former Treadwell Mine Complex area.
- Clams – Tribal members recall collecting steamer clams, mussels, and cockles from Sandy Beach, including areas south of the cave-in area. Members of the public occasionally harvest shellfish from the beaches near the former mines.

- Berries – Some tribal members or community visitors harvest berries from the trails within the Treadwell Mine Complex area.

Tribal and Community Health Concerns

The most frequently voiced concern is safety of children playing in the tailings on Sandy Beach. Other voiced exposure pathways of concern include migrating contamination into Gastineau Channel affecting fish, shellfish, and seaweed populations, harvesting shellfish for consumption, walking in the uplands, and collecting berries.

ATSDR involvement at the site. ATSDR first learned of concerns in the 2018 petition from DIA. DIA expressed health concerns about touching the beach sediments or eating shellfish from the beaches near the former mines. We gathered information from the DIA tribal council and staff, tribal members, the City and Borough of Juneau, various agencies of the State of Alaska (Department of Health and Social Services, Department of Environmental Conservation, Department of Fish and Game, and Department of Natural Resources) and community groups. We conducted two site visits in July 2019 and February 2020 to listen to concerns and talk about expectations of the report. We toured the site with a tribal elder and conducted key informant interviews with tribal elders to determine past and current relationships with the site. We have talked to several members of the public about their concerns using the park and trails. Here is a summary of the community and tribal concerns:

Health effects

- increase in cancer
- fear of getting sick because of past exposures

Personal and community safety

- shellfish safety, shellfish contamination
- children playing on the beach, touching the tailings
- children playing at the park, touching the tailings that have blown into the park
- touching contaminants on the trail
- harvesting berries at the mine
- fear of the resurfacing of buried contaminants

Quality of life

- lack of access to safe, clean, abundant, and legally harvestable shellfish and other seafood

Agency actions

- lack of cleanup and insufficient investigation; unknown contaminants
- insufficient sediment sampling, especially deeper than the surface of the beach
- permit restrictions for tribal use of shellfish

At the request of tribal members, ATSDR compiled a list of questions asked by tribal and community members, and addressed them in Appendix B.

Discussion

Exposure Overview

People walk on the beach, play in the sand, and occasionally harvest clams, mussels, or cockles on the beach at the former Treadwell Mine Complex. Nearby crab pot buoys in Gastineau Channel can be seen from the shoreline. The tailings from the former Treadwell Mine Complex form sandy beaches that are a recreational destination for tribal and community members in the greater Juneau area. The upland area has trails, former mine debris, and mine building foundations.

To evaluate health effects of exposure, we must first determine 1) what people are doing or have done at the site, 2) what and how much of each chemical is present at the site and if the concentration has changed over time, and 3) estimate who, where, when, and how long people have been in contact with site contaminants. To do this we rely on environmental data sets collected by agencies or organizations. Sometimes we cannot estimate what has happened in the past because there are no data that represent conditions at that time. Table 1 describes how people may have been exposed to metals from the former Treadwell Mine Complex.

As part of our public health assessment process, ATSDR reviewed available environmental data from EPA, state environmental agencies, or other organizations. First, we screened the beach sediment and upland soil samples for potential health risks by comparing the maximum contaminant levels from the site to ATSDR's media-specific comparison values. If any contaminants were present above the applicable comparison value, the risk posed by that contaminant was further evaluated. Comparison values are not available for contaminant exposures from food, so all the shellfish data were evaluated without a screening step. Our evaluations of shellfish, beach sediment and upland soil are detailed below and in Appendices C and D.

Table 1. How people may be exposed to hazardous substances from the Former Treadwell Mine Complex at Sandy and Red Beaches, Douglas, Alaska

Exposure Pathway	Source?	Where?	Doing What?	How are they exposed?	Who?	When?
1) Shellfish (butter clams, cockles, mussels)	Algal blooms (paralytic shellfish toxin or "PST")	Gastineau Channel	Eating shellfish all year long collected at low tide	- Eating any shellfish at any frequency	Tribal and community members including children	Past Present Future

Exposure Pathway	Source?	Where?	Doing What?	How are they exposed?	Who?	When?
2) Shellfish (cockles, softshell, littleneck clams, mussel, crab, sea cucumber)	Leftover waste from historical gold mining activities	Mine tailings on Sandy and Red Beaches	Eating shellfish as a source of food all year (night or day) collected at low tide	- Traditional diet - Ceremonial /occasional diet (once a month)	Tribal and community members including children	Past Present Future
3) Shellfish (crab)	Leftover waste from historical gold mining activities moving into channel	Gastineau Channel	Eating crab as a source of food all year (except summer)	- Traditional diet - Ceremonial /occasional diet (once a month)	Tribal and community members including children	Past Present Future
4) Beach sediment (recreation)	Leftover waste from historical gold mining activities	Mine tailings at Sandy and Red Beaches up to 1 foot deep	Playing or walking on beach; harvesting shellfish in the sediment	- Touching sand or mud with bare hands or feet - Accidentally ingesting sand or mud	Tribal and community members including children	Past Present Future
5) Beach Sediment (mining)	Leftover waste from historical gold mining activities	Mine tailings at Sandy and Red Beaches	Digging into beach tailings during excavation of large holes (3 ft. deep by 6 ft. wide) for a month or? more (episodic)	- Touching sand or mud with bare hands or feet - Accidentally ingesting sand or mud	Recreational miner	Past Present Future
6) Upland Surface Soil – Park	Deposition of sand mine tailings from the beach near historical gold mining activities	Savikko Park	Playing at the park all year long every day	- Touching sand or dirt with bare hands or feet - Accidentally ingesting sand or mud	Tribal and community members including children	Present Future
7) Upland Surface Soil – former mine areas	Leftover waste from historical gold mining activities	Community Recreation al Area at the Mine Complex Area	Playing or walking on Mine Complex Trails all year	- Touching sand or mud with bare hands or feet - Accidentally ingesting sand or mud	Tribal and community members including children	Past Present Future

Contaminants in Shellfish

ATSDR does not have health-based comparison values to screen the shellfish data. Exposure and health risks of contaminants in shellfish are evaluated in the next section. ATSDR's key findings from the data review and screening process for shellfish are as follows:

- Metals and cyanide were detected in shellfish (clams, mussels, cockles) and sediment collected near the former Treadwell Mine Complex as well as a background area in southeast Alaska. Limited site data were available for crab, sea cucumber, and snail.
- Levels of metals in shellfish are like those in non-contaminated areas (metals occur naturally in sand and rocky shores of southeast Alaska). Levels of arsenic in shellfish at the site were just slightly higher than those found at background areas and in market basket studies. Similarly, there are natural sources of cyanide in nearshore waters, and cyanide levels were similar in shellfish from the site and the background area.
- PST measured monthly in butter clams at Point Louisa, north of Juneau, has exceeded Alaska's regulatory limit for commercial use since January of 2016. In blue mussels and cockles, the commercial limit has been exceeded less frequently.

Paralytic Shellfish Toxins (PSTs) in Juneau-area Shellfish are concerning.

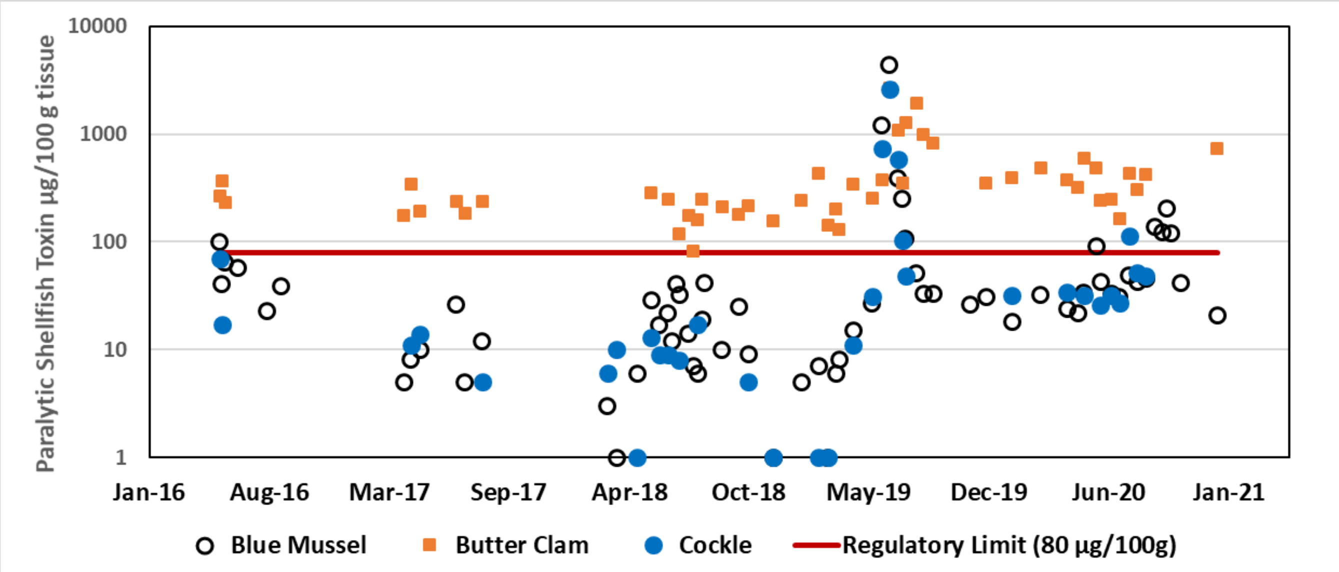
The presence of PSTs is a natural phenomenon that is not related to the mine, but it is discussed in this report due to the potential severity of health impact.

PSP is a serious illness caused by eating shellfish contaminated with dinoflagellate algae from the genus *Alexandrium* that produce harmful saxitoxins [RaLonde 1996]. Symptoms of PSP may include nausea, vomiting, diarrhea, abdominal pain; tingling or burning lips, gums, tongue, face neck arms, legs, and toes; shortness of breath; dry mouth; a choking feeling; confused or slurred speech; and lack of coordination. In rare instances, PSP may cause death. Get medical help immediately if you experience any of these symptoms after eating a shellfish meal.

ADEC routinely tests commercially harvested shellfish to determine whether saxitoxin levels exceed safety standards. Because testing is not performed at Alaska's recreational beaches on a routine basis, Alaska's state health department does not consider personally harvested shellfish from Alaska safe to consume [McLaughlin and Castrodale 2010].

The Southeast Alaska Tribal Toxins partnership works to detect harmful algal blooms by sampling coastal waters for potentially harmful plankton species and testing shellfish for high levels of toxins. PSTs have been a problem in shellfish from the Juneau area for decades; the issue is mentioned in a report from 1988 [E&E 1988]. In the Juneau area, shellfish are collected by the Central Council of Tlingit and Haida Indian Tribes of Alaska at Auke Rec (Pt. Louisa) and Amalga Harbor. Shellfish samples are analyzed by the Sitka Tribe of Alaska Environmental Research Lab. Results are posted to the Southeast Alaska Tribal Ocean Research (SEATOR) website at www.seator.org along with interpretive information for the public. Relatively recent PSP data from the Juneau area are shown in Figure 6.

Figure 6. Comparison of Paralytic Shellfish Toxin (µg/100 g tissue) in shellfish north of Juneau from Auke Bay at Point Louisa between March 2016 and January 2021 with Alaska's regulatory limit for commercial shellfish.



Source: Alaska Harmful Algal Bloom Network (www.seator.org). Shellfish collected by the Central Council of Tlingit and Haida Indian Tribes of Alaska, and analyzed by the Sitka Tribe of Alaska Environmental Research Lab.

Figure 6 shows that butter clams from Point Louisa routinely have PST levels above health-based regulatory limits. Butter clams from the area are not safe to eat. ATSDR recommends that people avoid harvesting butter clams from the Juneau area. Consumption of butter clams with high levels of PST could result in serious illness or death. Data indicate that cockles are sometimes, but not always, safe to eat from the Pt. Louisa area. PST levels can vary substantially among shellfish species and among beaches, and toxin levels can change rapidly over time [RaLonde 1996]. Hence, gathering and consumption of bivalves from the Juneau area will always entail some health risk. Health risks can be lowered by choosing shellfish species less likely to contain high levels of toxin, and by checking the SEATOR website to gauge current conditions prior to harvesting. In crabs, PSTs are most abundant in the hepatopancreas [Deeds et al. 2008], so ATSDR recommends that people remove the viscera (organs) from harvested crabs before cooking or eating the crab.

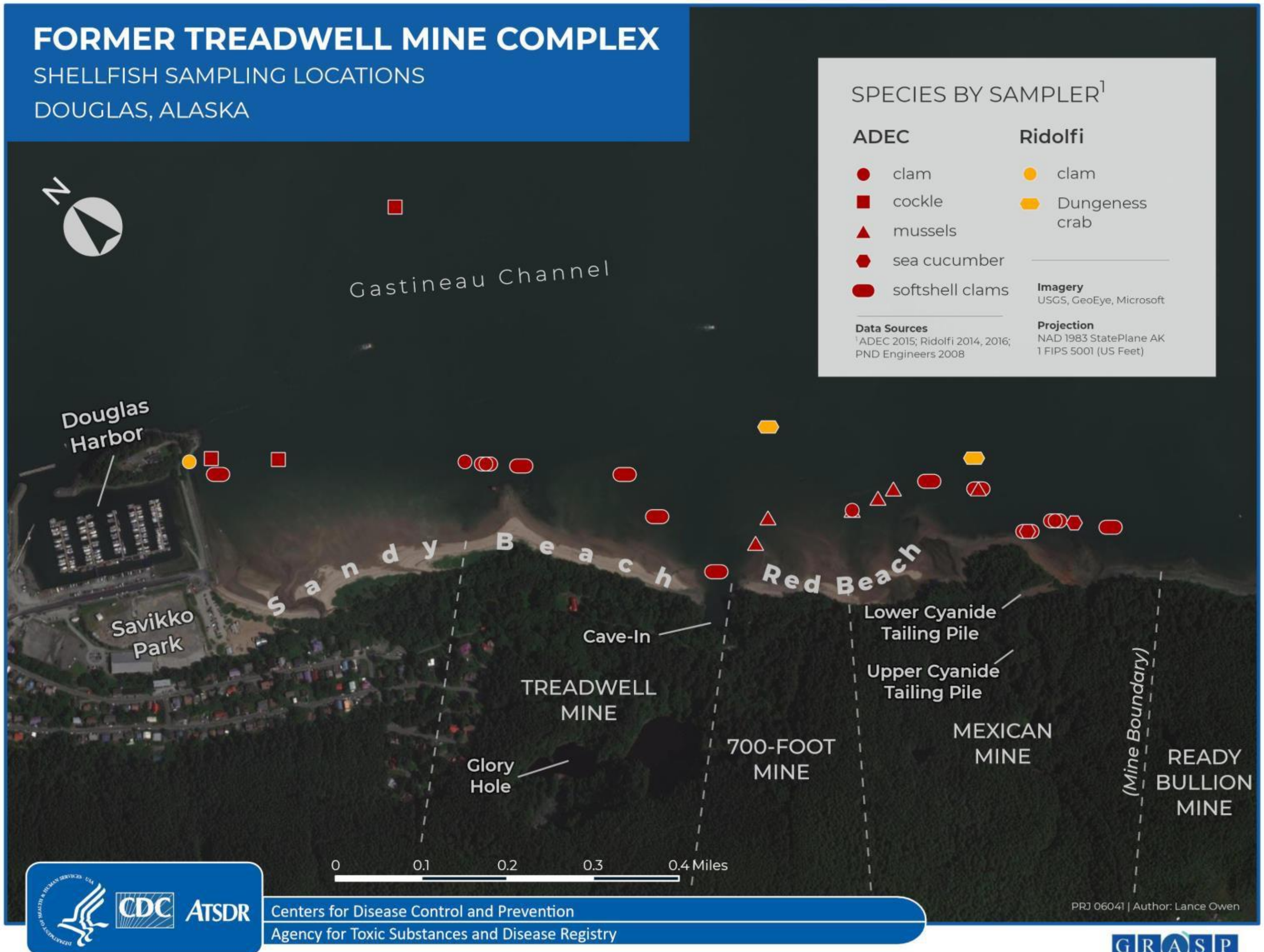
Evaluation of Health Effects from Eating Site-related Chemicals in Shellfish

This section briefly explains how ATSDR estimated the noncancer and cancer health risks associated with consumption of site-related contaminants in shellfish from the site. It includes how ATSDR determined shellfish consumption rates used to estimate exposures. It also discusses the further evaluation we performed for chemicals and exposure scenarios that warranted a closer look. The health evaluation and results are described in more complete detail in Appendix D, and all modeling outputs are provided in Appendix E.

Shellfish chemical data used in the public health assessment are described in Appendix C. ATSDR used all data sets with some modification in evaluating risks from consuming shellfish harvested near the former Treadwell Mine Complex. The shellfish data collected at the site in 2014 most likely represent current site conditions [Ridolfi 2014; ADEC 2015]. Figure 7 displays the sampling locations for shellfish at Sandy and Red Beaches. ATSDR compared the levels in these shellfish with those found in shellfish collected at remote non-contaminated sites, as these metals also occur naturally in southeast Alaska environments [EPA 2018; Rudis 2001].

Either ADEC or DIA collected samples for metals analysis in clam (n=10), mussel (n=11) and cockle (n=4) tissue; ADEC also analyzed cyanide in some of those samples. There are also limited data for sea cucumber and crab tissue (Table C2, Appendix C). For more information about these data sets and the inclusion or rejection of data see Appendix C. ATSDR does not have comparison values for food, so all health risks for shellfish consumption were evaluated further.

Figure 7. Shellfish sample locations, Former Treadwell Mine, Douglas, Alaska



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Shellfish Consumption Rates

ATSDR reviewed the DIA and ADEC reports and estimated the amount of each contaminant that a person might be exposed to from eating shellfish. ATSDR estimated how much of a particular food item a community member eats, in order to calculate potential health risks of chemical intake from eating the food. ATSDR used two different approaches to estimate food consumption and resulting potential health risks.

Once-a-month diet. ATSDR estimated an upper-end possible current consumption amount, based on the limited amount of shellfish observed at the beach, anecdotal reports of recreational harvest from community or tribal members, and the potential for occasional ceremonial harvests. The upper-end current consumption amount is estimated to be twelve meals per year for each food item. A meal size is assumed to be 4 ounces for children aged 2 to < 11 years, and 8 ounces for older children and adults. This exposure scenario is henceforth referred to as the "once-a-month diet."

Traditional diet. A "traditional diet" scenario was also determined to consider possible historical usage in the Juneau area, prior to the constriction of Tribal harvests due to changing Alaska laws and increased environmental contamination. In-depth subsistence harvest surveys are available for several southeast Alaska communities designated as "subsistence" communities by the State of Alaska [Sill 2017a, Sill 2017b]. Species-specific shellfish harvest rates were evaluated for the nearby communities of Yakutat, Hoonah, and Angoon. Annual pounds of harvested usable meat were divided among species-specific shellfish users per capita to calculate species-specific consumption rates. ATSDR used consumption rates for Hoonah to represent a traditional diet if DIA Tribal members could harvest shellfish for consumption.

Table 2 presents the protective assumptions used to evaluate exposures to metals and cyanide from eating shellfish. Because of the health benefit from eating seafood, the American Heart Association recommends eating two four-ounce servings of fish per week [Lichtenstein et al. 2021].

Table 2. Estimated shellfish consumption rates based on a once-a-month diet, a traditional diet, or the AHA-recommended two 4-ounce seafood meals per week.

	Once-a-Month diet (number of meals per year)*, §	**Once-a-Month diet (grams per day for an adult)***	**Traditional diet (number meals per year)†, §**	**Traditional diet (grams per day for an adult)†**	**AHA recommended seafood diet (number of 4-ounce meals per year) ‡**	**AHA recommended seafood diet (grams per day) ‡**
Cockle	12	7.4	53	33	104	32
Clam	12	7.4	50	31	104	32
Dungeness Crab	12	7.4	22	14	104	32
Mussel	12	7.4	2	1.2	104	32
Sea Cucumber	12	7.4	1	0.67	104	32

Sources and Notes:
*Reports of shellfish harvest from Tribal and community members [ATSDR 2020]
†Alaska Dept of Fish & Game Technical Paper #399 for Hoonah harvest rates [Sill 2017a]
‡American Heart Association (AHA) recommendation of two fish meals per week [Lichtenstein et al. 2021]].
§ Scenarios assume a meal size of 4 ounces for children aged 2 to eleven years, and 8 ounces for older children and adults.

Noncancer Health Effects from Eating Shellfish

ATSDR estimated health risks for exposure to metals from eating shellfish, by calculating site-specific exposure doses for various exposure scenarios. A hazard quotient, which is the exposure dose divided by the minimal risk level dose that doesn't cause health effects, is calculated for each chemical/exposure scenario. A hazard quotient above 1.0 does not indicate a threshold for health effects; it simply indicates that a more in-depth risk evaluation is needed. Appendix D shows numerical results, details about modeling methodology and inputs, and a more in-depth discussion of exposures with hazard quotients above 1.0.

The following shellfish consumption estimates did not exceed minimal risk levels (MRLs) or other benchmarks and were not evaluated further.

- In both the once-a-month diet and traditional diet, eating cockles, dungeness crabs, and mussels, did not pose a health threat. No MRLs were exceeded for cockles, dungeness crabs or mussels collected near the former Treadwell Mine site. Consumption of these shellfish were not evaluated further.
- In both the once-a-month diet and the traditional diet for all shellfish, levels of methyl mercury, selenium and cyanide do not pose a health threat. ATSDR conservatively assumed that the mercury measured in shellfish was in the more toxic methyl mercury form. No MRLs were exceeded for methyl mercury, selenium, or cyanide, for any shellfish species or exposure scenario evaluated. The toxicity and risks associated with these chemicals in site shellfish are minimal and are not further evaluated.

Cadmium, copper, and inorganic arsenic in clams were evaluated further. Copper in sea cucumbers was evaluated further. Since cadmium, copper, and inorganic arsenic were the only chemicals with some hazard quotients at or above one, ATSDR conducted a more in-depth evaluation of arsenic, cadmium, and copper exposures and associated hazards. ATSDR also performed an evaluation of lead in clams and cockles. More in-depth discussions of the health evaluations are in Appendix D.

Cadmium in Clams

Traditional Diet. The traditional diet scenario did not pose a health concern for children over the age of 5 years or for adults, regarding past cadmium exposures from clam consumption. Hazard quotients were below 1.0 for these older age groups (Table E1c).

The hazard quotient for chronic exposure to cadmium was 1.0 for consumption of clams from the former Treadwell mine site by children two to six years old, at a traditional (Hoonah) diet rate of fifty-one 4-ounce meals per year (Table E1c). In the distant past people may have been exposed at this level; elders we interviewed did not recall such a prolific use of clams from the Sandy or Red beach areas during their lifetimes. ATSDR's chronic oral MRL is based on a health outcome of proteinuria (a biomarker of kidney function) by the age of 55 years, after a lifetime of exposure [ATSDR 2012]. The MRL includes a three-fold safety factor above the cadmium level at which proteinuria was observed in some older people following a lifetime of exposure.

The intake of cadmium from clams at the site did not pose a human health hazard for young children in the past for at least three reasons:

1) It is unlikely that young children historically consumed as many as fifty-one 4-ounce meals of clams from Sandy or Red beaches per year.
2) The cadmium dose under the traditional diet scenario is three times lower than the dose that caused a biological change in human studies.
3) The chronic oral MRL is based on a biochemical health effect that occurred in some people over 55 years old, following a lifetime of exposure. That outcome would not occur in childhood following cadmium exposure at the traditional diet level, nor would children experience this health effect in adulthood if the traditional diet were consumed for a lifetime (the adult hazard quotient was below 1.0).

Once-a-month diet. Levels of cadmium were not of health concern and fell below a hazard quotient of 1.0.

Copper in sea cucumbers and clams

Copper is an essential nutrient for humans. As such, humans have evolved homeostatic mechanisms to maintain blood copper concentrations in an optimal range for health. Exposure to dietary copper at environmentally relevant doses is not generally of chronic health concern because excess copper can be excreted, except by those with rare genetic disorders [Burkhead and Collins 2021]. However, there are provisional intermediate and acute MRLs for ingestion of copper. Health effects consist of gastrointestinal upset and are temporary; they are related to a particular eaten meal rather than to cumulative exposures over time. In this case, it is the individual meal size that determines risk, rather than a cumulative exposure from many meals over time. Therefore, calculated risks are the same for either the traditional diet or once-a-month dietary scenarios.

The health effect upon which both the intermediate and acute provisional copper MRLs are based is temporary gastrointestinal symptoms such as nausea, abdominal pain, diarrhea and/or vomiting [ATSDR 2022]. The key studies upon which the MRLs are based were both human exposures from copper sulfate in drinking water, so its direct application to copper exposures in food may overestimate actual risk. Copper absorption in food ranges from 15-97%, depending on copper content and composition of the diet [Stern et al. 2007]. The variability in copper bioavailability from foods adds uncertainty regarding the toxicity of copper consumed within food. ATSDR's provisional copper MRLs have an uncertainty factor and are three times lower than the level at which no effects were observed.

Copper is an essential nutrient for humans, so harmful effects can occur if a person does not consume enough copper in their diet. Copper is essential for bone formation, heart function, fat metabolism, immune function, brain development, and maturation of blood cells [Danks 1988]. People should try to consume an adequate amount of copper in their diet, that is neither too low nor too high. Evidence indicates that an optimum dietary copper intake would fall between the recommended dietary allowance (RDA) and the upper tolerable intake level (TUL) established (for each age group and pregnancy status) by the U.S. Institute of Medicine [2001].

Sea cucumbers in the once-a-month or traditional diets. Copper was present in sea cucumbers at the site at a maximum concentration of 14 ppm. Hazard quotients for acute copper exposures from sea cucumber consumption under either dietary scenario ranged from 2.0 (for adults) to 4.6 (for small children). Risk estimates for sea cucumber are uncertain because they are based on only two samples. When evaluated in context of the RDA and TUL, copper intake from a standard-sized meal of sea cucumber only exceeded the TUL for the youngest age group evaluated (2 to < 6 years of age) (Table D3). Since advised copper intake is easily exceeded in young children that eat sea cucumbers from the site, parents may wish to avoid serving sea cucumbers to children under the age of six to avoid potential stomach upset.

Clams in the once-a-month or traditional diets. Hazard quotients for acute copper exposures from clam consumption were 1.2 for children under the age of six, under either diet scenario. When evaluated in context of the RDA and TUL, copper intake from a standardized meal of clams did not exceed the TUL for any age group, including young children. Therefore, site clams may be considered a good source of dietary copper; clam consumption does not pose a health risk of copper over-exposure (Table D3).

Arsenic in clams in the traditional diet

Inorganic arsenic hazard quotients were only above 1 for some clam exposure scenarios. There are two main reasons why inorganic arsenic was a greater problem in clams than in other types of sampled shellfish. First, the traditional diet (Hoonah) consumption rate of clams was high, at 51 meals per year. Only cockles rivalled that consumption rate, at 53 meals per year for the traditional diet scenario. Second, although the sample size was very limited, the available data showed that the percentage of total arsenic present in the more toxic inorganic form (51%) was much higher in clams than is generally seen in other types of seafood (often <1%).

Clams in the traditional diet. The hazard quotient for acute exposure to inorganic arsenic in clams was only above one (1.6) for the 2- to < 6-year-old age group. The MRL for acute inorganic arsenic exposure is based on data from an episode of arsenic contamination of soy sauce in Japan in the 1950s [Mizuta 1956]. Facial edema and gastrointestinal symptoms such as nausea, vomiting and diarrhea were the critical effects [ATSDR 2007]. The MRL for acute inorganic arsenic exposure is based on a LOAEL rather than a NOAEL; a ten-fold safety factor was incorporated into the MRL to reflect that source of uncertainty. The inorganic arsenic dose for young children exposed acutely to site clams is 0.008 mg/kg/day, which is less than two-fold above the acute MRL of 0.005 mg/kg/day, and more than six times lower than the LOAEL of 0.05 mg/kg/day at which health effects were observed in the study from Japan. Considering the safety factor of ten built into the MRL for use of a LOAEL, the possibility of over-estimation of the percent arsenic present in the inorganic form, and the unlikelihood that arsenic within the clams was completely bioavailable, it is unlikely that arsenic in clams from the site poses an acute health hazard to young children.

The hazard quotient for chronic exposure to inorganic arsenic in clams exceeded one for all age groups when the traditional diet scenario was applied, ranging from 1.6 (in adults) to 3.7 (in young children). The MRL for chronic inorganic arsenic intake is based on exposures from well water, and the health effect was skin lesions. A safety factor of three is built into the chronic MRL to account for variability in sensitivity among humans. The NOAEL dose from the key MRL study for chronic oral inorganic arsenic exposure was 0.0008 mg As/kg/day. That NOAEL dose was only exceeded in the youngest age group evaluated in Treadwell (children 2 < 6 yrs.), who consume an estimated dose of 0.0011 mg As/kg/day under the traditional diet scenario. This dose in young children is more than twelve-fold lower than the LOAEL of 0.014 mg As/kg/day, at which dermal health effects were observed in the key study. Arsenic in clams from the site do not pose a chronic health hazard at the site because the percent of inorganic arsenic may have been over-estimated, and it is unlikely that the arsenic within the clams was completely bioavailable or that anyone eats 51 meals per year of clams from the site. People can reduce their exposure to inorganic arsenic in clams by choosing varied species of clams rather than always choosing softshell clams, which often contain higher amounts of inorganic arsenic than other clam species (Appendix D). It is also possible to reduce arsenic exposure from softshell clams by removing the siphon before consuming it [Kerns et al 2017].

Clams in the once-a-month diet. The hazard quotient for acute exposure to inorganic arsenic in clams was only above one (1.6) for the 2- to < 6-year-old age group. This exposure and health effect were discussed above and are similar to the traditional diet.

Lead in clams and/or cockles

The health risks posed by lead at a site are evaluated differently than other chemicals. Health-based comparison values for soil or food have not been developed for lead, because researchers have determined there is no "safe" blood lead level. The most meaningful predictor of potential health implications from lead exposure is the concentration of lead in the blood of an exposed individual.

Health assessors often use a modeling approach to predict a theoretical increase in blood lead levels that might occur from environmental exposures. ATSDR used EPA's integrated exposure uptake biokinetic model (IEUBK) [EPA 2021] to estimate blood lead levels of children eating shellfish from the site at a consumption rate of once a week over 90 days or more, which is required to achieve a steady state of blood lead concentrations in the model. The only shellfish with sufficient consumption frequency to use the IEUBK model were clams and cockles under the traditional diet scenario (Hoonah consumption rate).

ATSDR used defaults in the IEUBK model for dietary data inputs with the exception that site clams and/or cockles were substituted for other types of meat in a percentage of a child's diet. ATSDR derived the number of clam/cockle meals per year from the traditional (Hoonah) diet (Table 3) (Sill 2017a)]. The number of clam and cockle meals per year were 50 and 53 meals, respectively. Either of these meals represent approximately 1 meal per week. We assumed that a child eats one meat meal per day, so on the days the child eats shellfish they are not consuming any other type of meat. At a consumption frequency of 1 day per week, the percentage of meat as clams or cockles is 1/7 or 14%. Eating both one meal of clams and one meal of cockles per week would constitute 2/7 or 28% of total weekly meat intake (Appendix D, Table D7).

The probability of predicted blood lead levels above 5 µg/dL from consuming site clams and/or cockles at the traditional diet rate was low, and not expected to increase blood lead much above the levels obtained from consuming other meat sources in the United States.[1] ATSDR calculated a

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[1]In October 2021, CDC updated the blood lead reference value (BLRV) from 5 µg/dL to 3.5 µg/dL [CDC 2021]. However, lead models are not currently validated for levels below 5 µg/dL. Therefore, ATSDR uses 5 µg/dL in the models in our health evaluations until the updated BLRV of 3.5 µg/dL can be verified by EPA in their models.
CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard. States independently determine action thresholds based on state laws, regulations, and resource availability. CDC encourages healthcare providers and public health professionals to follow the recommended follow-up actions based on confirmed blood lead levels (https://www.cdc.gov/nceh/lead/advisory/acclpp/actions-blls.htm).

0.80, 0.38, or 1.9% chance of a blood lead above 5 µg/dL for a child eating clams one day a week, cockles one day a week, or both (each once in a week), respectively (Appendix D).

Evaluation of Cancer Risk from Eating Shellfish

Inorganic arsenic was the only carcinogen evaluated in this report. ATSDR estimated a theoretical excess lifetime cancer risk for inorganic arsenic exposure from both the traditional (Hoonah) and one-meal-a-month diets, using the same exposure scenarios described previously for noncancer health endpoints. Cancer risk calculations are described in Appendix D, and the risks are shown in Table D6.

The cancer risk calculation estimates a theoretical excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of 1×10^{-6} predicts that one additional cancer case may occur in a population of 1 million people exposed at the same level. EPA uses protective models to derive a cancer slope factor for each carcinogen, which is used to calculate a theoretical estimate of risk. The true or actual risk is unknown and could be as low as zero [EPA 2005].

The U.S. EPA uses a range of 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) to make risk management decisions at Superfund sites. These theoretical cancer risk estimates apply to people with the same exposure assumptions (e.g., arsenic concentration in food, food ingestion rate, specified duration), and cannot be viewed as a precise cancer risk for an individual or a community where these assumptions vary throughout the population.

According to the American Cancer Society, the overall probability that residents of the United States will develop some type of cancer during their lifetime is 40% for men and 39% for women (almost 1 in 2) [ACS 2020]. One excess cancer case per million people exposed at the same level in a population would be very difficult to detect atop the high background cancer incidence.

Table D6 shows that clam consumption poses the greatest risk of excess lifetime cancer incidence among the shellfish species analyzed. Excess cancer incidence is predicted to be of moderate concern though it is above EPA's risk range of 1 in 10,000 (1×10^{-4}) under both the traditional (Hoonah) diet and one-meal-a-month scenarios. **The excess cancer risk from consumption of inorganic arsenic in clams is not all site related**. Ingestion of inorganic arsenic in clams from the background area at the traditional (Hoonah) consumption rate also poses a similar cancer risk above EPA's risk range which is of moderate concern.

There are important health and cultural benefits of seafood consumption, so it is not recommended that tribal and community members reduce their level of seafood consumption because of contaminant concerns. One way people can reduce their potential for negative health effects is to choose a variety of seafood types as part of a balanced diet. If people would like to reduce their exposure to inorganic arsenic in seafood, they can choose species other than softshell clams for consumption. Or, by removing the siphon from softshell clams prior to consumption, they can continue to enjoy softshell clams while reducing their arsenic exposure.

Background metals levels in shellfish from Southeast Alaska. All metals detected in site shellfish are also found in shellfish sampled from non-contaminated sites. These samples are sometimes called "background" samples because they represent local conditions in undisturbed areas that are close to, but not affected by, the site. Metals occur naturally in the beach sediment and rocky shores of southeast Alaska, and in Alaska soil, because they are a natural part of Alaska's mineralized geology. Background mussel samples were collected from Lynn Canal (north of the Juneau area) prior to establishing the Kensington Mine [Rudis 2001]. Background crab and clam samples were taken from Browns Bay as reported in the Salt Chuck Mine Superfund site remedial investigation [EPA 2018]. The background levels of metals in shellfish from these studies are summarized in Table C3 within Appendix C. Our discussion here focuses on arsenic and copper. These were the only chemicals in site shellfish with hazard quotients above 1.

It was not possible to perform rigorous statistics on the background and site data sets because the number of samples was too small, and there were some methodological differences between the studies. The range of total arsenic concentrations in clams, dungeness crabs and mussels from Sandy and Red Beaches were similar to arsenic levels found in the background studies (Figure D1). Average copper levels in mussels from the former Treadwell Mine Complex were nearly identical to those found in mussels from the background area. Average copper levels in clams from the site were slightly higher than copper levels from the background area (Figure D2).

Grocery store shellfish also contain arsenic and copper (Comparison to FDA's market basket analyses). ATSDR evaluated the levels of total arsenic (Table D4) and copper (Table D5) found in site-related shellfish in the context of arsenic and copper levels found in market basket foods that contained seafood. The market basket survey performed by the Food and Drug Administration (FDA) is a periodic analysis of chemicals and nutrients found in food samples bought and prepared from grocery stores around the U.S. [FDA 2017].

The foods from the FDA market basket survey are not the same as the unprepared shellfish samples analyzed from the former Treadwell Mine site, so the arsenic and copper levels are not directly comparable. Tables D4 and D5 illustrate that grocery store foods also contain arsenic and copper; they should not be assumed to be "safer" or "less contaminated" than locally harvested foods. All foods contain both chemicals and nutrients, and a variety of different foods should be consumed and enjoyed as part of a healthy, balanced diet.

Contaminants in Sediment on Beaches

ATSDR identified site-specific and background sediment data for review. Data were available for 18 metals including inorganic arsenic and methyl mercury as well as cyanide. The maximum value for each metal identified was screened with residential soil health-based comparison values. Based on the screening, no chemicals other than lead will be evaluated further. Lead is present at low concentrations and is discussed in Appendix D and in the text. Data on sediment more than 3 feet deep were not available for review. Information on dredge deposits or tailings in subtidal areas in Gastineau Channel was not available for review.

Several studies characterized the sediment (beach tailings) associated with the former Treadwell Mine Complex. The site sediment data appeared to be consistent among the reports and had similar detection limits (Figure 8). The most comprehensive study used incremental sampling methodology [Nortech 2013a]. Tribal reports [Ridolfi 2014, 2016] provided additional data regarding methyl mercury and inorganic arsenic speciation. The data from all these reports were screened (Appendix C, Table C4). In summary,

- The maximum concentrations of most metals in Sandy Beach sediment fell within or below the range of background concentrations, and below ATSDR CVs for residential soil.
- The maximum concentration of total chromium in site sediment was above the ATSDR CV for hexavalent chromium, but well below the CV for trivalent chromium. Total chromium levels at the site were below background chromium concentrations. There is no known source of hexavalent chromium at the site.
- Methyl mercury and mercury maximum concentrations in site sediment fell below ATSDR's reference dose media evaluation guide (RMEG) and the EPA regional screening level (RSL) for residential soil. Levels of background methyl mercury were not available.
- The health risks posed by lead at a site are evaluated differently than other chemicals. Health-based comparison values for soil or food have not been developed for lead, because researchers have determined there is no safe amount of lead exposure. Exposure to lead in sediment was evaluated further in the next section.

Evaluation of Health Effects from Lead in Sediment

Metals and cyanide found in the surface sediment at Sandy and Red Beaches were not at levels that could cause health problems for children (or adults) playing or walking at the beach or nearby Savikko Park. Only lead was evaluated further and concentrations at the site are not expected to result in an elevated blood lead level in exposed individuals.

The health risks posed by lead at a site are evaluated differently than other chemicals. Health-based comparison values for soil, sediment, or food have not been developed for lead, because researchers have determined there is no safe amount of lead exposure. The most meaningful predictor of potential health implications from lead exposure is the concentration of lead in the blood of an exposed individual. Based on a survey of children's blood across the United States, the CDC blood lead reference value (BLRV) was recently lowered from 5 to 3.5 µg/dL [Ruckart 2021]. CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard.

The average lead concentration from sediment (beach sand) at the site is 11.4 ppm and ranged from 5.58 to 58.2 ppm. United States Geological Survey (USGS) estimated the arithmetic mean for soil in Alaska as 14 ppm (n=437) with samples ranging from less than 4 ppm (detection limit) to 310 ppm [Gough et al. 1988]. As the average lead concentration in site sediment (beach sand) is below the average soil lead concentration in the state, there is likely not a site-related source of lead.

ATSDR used EPA's integrated exposure uptake biokinetic model (IEUBK) and incorporated the average lead concentration from sediment beach sand (11.4 ppm) as the concentration to which children are exposed to in the model. In October 2021, CDC updated the blood lead reference value from 5 µg/dL to 3.5 µg/dL [CDC 2021]. However, lead models are not currently validated for levels below 5 µg/dL. Therefore, ATSDR uses 5 µg/dL in the models in our health evaluations until the updated BLRV of 3.5 µg/dL can be verified by EPA in their models.

CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard. States independently determine action thresholds based on state laws, regulations, and resource availability. CDC encourages healthcare providers and public health professionals to follow the recommended follow-up actions based on confirmed blood lead levels (https://www.cdc.gov/nceh/lead/advisory/acclpp/actions-blls.htm).

The model predicts a geometric mean blood lead level for children playing at this location of 1.154 µg/dL and less than 0.091% probability that a child playing in this location every day for 90 days or more would have a blood lead higher than 5 µg/dL[2] (Appendix D, Figure Pb-1). This exposure scenario overestimates a child's exposure because it assumes daily visits to the beach, and still does not appear to appreciably increase the blood lead of a child visiting the site. This result indicates that lead levels in sediment (beach sand) do not pose a public health hazard.

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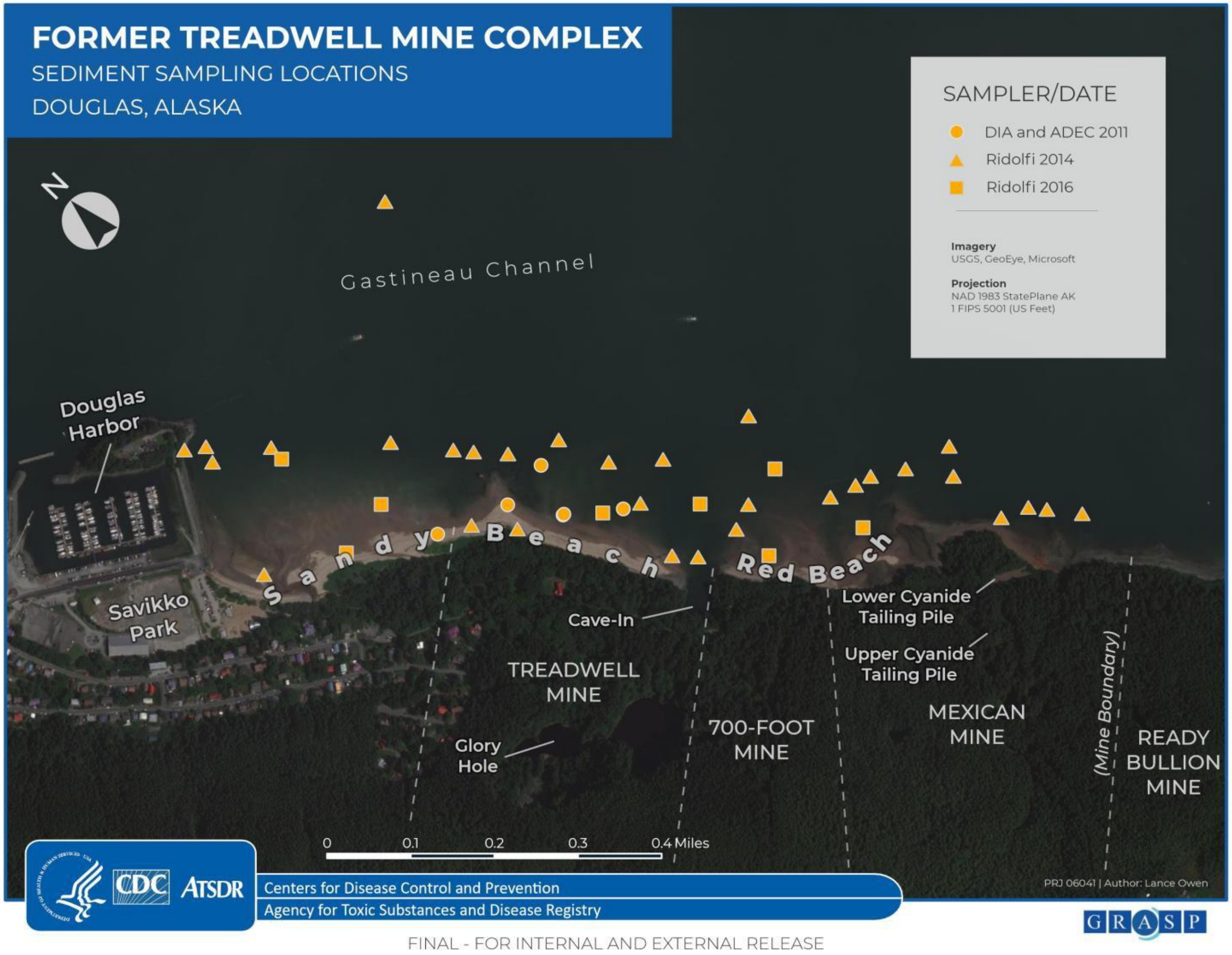
[2] In October 2021, CDC updated the blood lead reference value (BLRV) from 5 µg/dL to 3.5 µg/dL [CDC 2021]. However, lead models are not currently validated for levels below 5 µg/dL. Therefore, ATSDR uses 5 µg/dL in the models in our health evaluations until the updated BLRV of 3.5 µg/dL can be verified by EPA in their models.
CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard. States independently determine action thresholds based on state laws, regulations, and resource availability. CDC encourages healthcare providers and public health professionals to follow the recommended follow-up actions based on confirmed blood lead levels (https://www.cdc.gov/nceh/lead/advisory/acclpp/actions-blls.htm

Figure 8. Sediment sampling locations, Former Treadwell Mine Complex, Douglas, Alaska.



Contaminants in Upland Soil

More information is needed to evaluate exposures in the upland area of the historic mines, especially if the area is to be developed. Only one study looked at metals or cyanide in the upland area at the former Treadwell Mine Complex. The level of metals found in the capped areas over tailings at the Mexican Mine, upland from Red Beach, were not at levels that could cause health problems for people walking on them. Metal and cyanide levels in surface soil are similar to those in non-contaminated areas.

ATSDR found that characterization of potential mine contamination in the uplands above Sandy and Red Beaches has been limited. Many of the mine buildings and processing activities were in the upland areas. Some building foundations and old machinery are still present in the uplands area [CBJ 2010], and they may be a draw for curious hikers and historical mining buffs. Chemical contamination of those features and nearby areas is largely unknown.

The main characterization of uplands contamination that ATSDR identified was related to two tailings piles from operations of the Mexican Mine. The tailings piles contain wastes from ore concentrating practices, including use of mercury or cyanide. The upper tailings pile covers about 2,800 square feet and is located just downhill of the concentrate building, and the lower tailings pile covers about 9,100 square feet and is located near Gastineau Channel in the Red Beach area south of the foundry. Investigations in 1988, 1991, 1996, and 2006 found that soil samples from the tailing sites had higher concentrations of lead, zinc, arsenic, mercury, and cyanide than did background soil samples [Smith Bayliss LeResche 2006]. The upper tailings were revegetated in 1996 as part of a reclamation project, and the lower tailings were capped in 2007. ADEC classifies the site "Mexican Mine Mill Tailings" as "Cleanup Complete–Institutional Controls". The two caps must be maintained, and they must be covered with soil that will support a vegetated layer. A separate database record under the former name "Treadwell Mine Complex" (Hazard ID 25594) tracks information on the other portions of the site [ADEC 2020]. The institutional controls for these areas do not include signage.

There is also documentation of a cache of 26 fifty-five-gallon drums found along the Treadwell Trail, near the former Mexican Mine. The drums had contained a thick tar-like substance and were in poor condition, with several corrosion holes noted. The drums were removed in June 2016, as was the petroleum-contaminated soil underneath them [Nortech 2016]. That case achieved case closure with no further action required from ADEC in December 2016 [ADEC 2016].

Child Health Considerations

The potential for exposure and subsequent adverse health effects may be different for children than for adults. Children - including those in the womb - are susceptible to developmental toxicity that can occur at levels much lower than those causing other types of toxicity. Children are more likely to

- play outdoors in contaminated areas by disregarding signs and wandering into restricted locations,
- bring food into contaminated areas resulting in more hand-to-mouth exposures,
- receive higher doses of a contaminant because they are smaller,
- breathe dust and soil because they are shorter and therefore, closer to the ground, and
- have underdeveloped functional capacity of various organ systems and/or metabolic pathways resulting in different rates of detoxification.

The unique vulnerabilities of infants and children require special attention in communities that have contamination of their water, food, soil, or air. It is likely that children will play and/or dig in the sediment along public access points or shoreline residences. Thus, exposure scenarios in this public health assessment treated children as the most sensitive population being exposed.

Exposure doses were specifically estimated for children playing on the intertidal sediments of Sandy and Red beaches and eating shellfish from that area. Children from 2 years old to less than 6 years old are the children with behaviors most likely to result in highest exposures. Parents may wish to avoid feeding sea cucumbers to children in this age group, to avoid potential stomach upset from copper exposure.

Key Findings

ATSDR evaluated the hazards of eating a meal from shellfish collected from beaches near the historic mines once a month over a lifetime. We also evaluated hazards based on shellfish consumption rates documented for the nearby subsistence community of Hoonah. The levels of contaminants in sediment of the beaches did not raise health concerns and are not evaluated further. Lead is present at low levels in sediment and shellfish that do not raise health concerns.

Eating Shellfish

The most significant health risk associated with eating local shellfish is the possibility of contamination with PSTs. Consumption of high levels of PSTs can result in serious illness or death. Symptoms of PSP poisoning may include nausea, vomiting, diarrhea, abdominal pain; tingling or burning lips, gums, tongue, face neck arms, legs, and toes; shortness of breath; dry mouth; a choking feeling; confused or slurred speech; and lack of coordination. In rare instances, PSP may cause death. The riskiest type of shellfish to eat from the Juneau area is butter clams, which commonly contain PST levels above safety-based standards (Fig. 6).

Most shellfish collected from Sandy and Red Beaches did not contain site-related levels of metals at levels of health concern. Copper levels in sea cucumbers and clams were high enough to potentially cause stomach upset (stomach pain, nausea, diarrhea, or vomiting) in children under the age of six. While arsenic levels in softshell clams may be similar to those found in market seafood, small- to moderate- cancer risks were associated with eating a traditional food diet with a large number (51) of clam meals per year over a lifetime. These risks can be lessened by choosing clam species other than softshell clams for consumption, or by removing the siphon from softshell clams prior to consumption. Insufficient numbers of crab samples were collected from the Gastineau Channel to comprehensively evaluate their safety for human consumption.

Touching or accidentally swallowing sediment

Metals levels in sediment did not exceed health-based screening values and were not of health concern. Only total mercury was above background sediment levels in Southeast Alaska. The remaining metals in beach sand and sediment, which originated from historic mine tailings, were found at levels similar to those found in these background locations.

Historical Exposures to Metals in Mine Tailings and Shellfish

Data were not available to assess historical exposures of tribal members to metals and other contaminants from the mine. Historical exposures may have been higher in the past, prior to 1962 when the tribal village was burned and destroyed.

Types of Exposures that are Not Well Characterized at the Site

Some parts of the site environment were not sufficiently characterized to evaluate potential exposure pathways to human receptors. These include:

- ***Sediments in the lower tide zone of Sandy Beach***. In 2012, the City and Borough of Juneau retained Nortech to employ incremental sampling methodology to fully characterize soil and sediment in the Sandy Beach portion of Savikko Park [Nortech 2013a]. Some of the planned sampling areas, including sediments exposed during low tide, were not sampled due to logistical constraints. Characterizing those sediments would have better informed evaluation of shellfish harvesting exposures. However, it is unlikely that site-related contaminant levels would be higher in the lower tide zone than in the original tailings located between the low and high tide lines. Shellfish collected from the lower tide zone did not contain contaminants at levels of health concern.
- ***Distribution of contaminated mine tailings to Gastineau Channel***. Potential contamination of Gastineau Channel sediments with metals from mine tailings are not well characterized. Tailings may have moved from the site beaches to deeper sediments during storms, high wind events, and tidal action over the 100 years since the mines were active. The nearby Douglas Harbor has historically been impacted by mine contaminants, and dredge spoils from the harbor were placed in Gastineau Channel for decades. More recent dredging activities have been characterized and the impacted sediments have been capped, but historical dredging operations have not been similarly characterized or mitigated. It is possible that historically impacted sediments have become covered over time, but the actual contamination profile of Gastineau Channel has not been systematically characterized. An exposure pathway that could not be sufficiently evaluated, due both to insufficient sediment characterization and insufficient biological sampling, is the harvesting and consumption of crab from the channel.

- ***Sediments and sand deeper than three feet.*** Deep sand and sediment have not been characterized on site beaches. Recreational miners have been observed digging deeper than three feet to access minerals from areas above high tide at the site. ATSDR could not assess hazards to recreational miners associated with metals contamination at depth due to a lack of data.
- ***Upland areas of historical mining operations.*** Some upland areas of mining operations have been characterized. Notably, the upper and lower tailings piles have been characterized and mitigated by capping with long-term maintenance. Other upland areas of the site, which include historical building foundations and old mining equipment, have not been characterized for chemical contamination. These ruins are explored by recreational hikers and historical mining enthusiasts, and the uplands may become increasingly accessible to the public if the area is developed into an historical park.

Limitations and Uncertainties

Health risks from consuming inorganic arsenic in shellfish are uncertain because only total arsenic was measured in most shellfish samples.

Inorganic arsenic forms are the most toxic forms of arsenic. Arsenic is commonly found in seafood, but most arsenic in seafood is found in an organic form that is not toxic. When only total arsenic levels were measured in a shellfish sample, ATSDR used available data and protective assumptions to estimate the percentage of arsenic that was likely in the inorganic form in the sample. Because our assumptions were designed to err on the side of caution, we may have overestimated health risks from inorganic arsenic in shellfish.

Health risks from consuming methyl mercury in shellfish are uncertain because only total mercury was measured in most shellfish samples.

The most toxic form of mercury commonly found in marine and freshwater fish and other seafood is methyl mercury. Mercury is commonly found in seafood, including shellfish, and much of the mercury in seafood is often in the form of methyl mercury. When only total mercury levels were measured in a shellfish sample, ATSDR assumed that 100% of the mercury was in the more toxic methyl mercury form. This is a protective assumption; it is possible that we overestimated health risks from mercury in shellfish.

Small sample sizes and the lack of available data for certain potential exposure pathways limited our ability to answer some of the community's questions.

ATSDR was unable to fully assess the safety of crab harvest and consumption due to small crab sample numbers and a lack of understanding about the extent to which site contaminants may have affected the deeper-water sediments of Gastineau Channel. ATSDR was also unable to address historical exposures of Indian Village inhabitants to mining contaminants because environmental contamination was not assessed during the pre-1962 era.

Conclusions

ATSDR came to the following six conclusions.

1. **People who eat clams, mussels, cockles, or other bivalves from beaches in the Juneau area may experience paralytic shellfish poisoning (PSP). Butter clams are the shellfish species most consistently elevated with PSTs in the Juneau area and are particularly hazardous. The risk of paralytic shellfish poisoning is a public health hazard.**

   Basis for conclusion: People who eat clams, cockles, mussels, or other bivalves from beaches that have not been recently tested and cleared for PSTs could have serious health problems, including temporary paralysis, inability to breathe, and death in severe cases. The presence of PSTs is a natural phenomenon that is not related to the mine, but it is included in this report due to the potential severity of health impact.

2. **People that consume shellfish would ingest similar metal levels from site shellfish, grocery store shellfish, or shellfish collected from uncontaminated "background" locations. Two shellfish consumption scenarios resulted in additional metal exposure, that can be mitigated. Children exposed to copper from eating sea cucumbers on a traditional or once-a-month diet may experience temporary gastrointestinal symptoms. In the traditional diet, exposure to inorganic arsenic in clams from the site, grocery store, or an uncontaminated location poses a moderate concern for increased cancer risk.**

   Basis for Conclusion: Copper levels in sea cucumbers were high enough to potentially cause acute gastrointestinal symptoms such as stomach pain, nausea, diarrhea or vomiting in children under the age of six, following a single 4-ounce meal. These effects would be temporary.

   In a traditional food diet containing 51 clam meals per year for a lifetime, exposure to inorganic arsenic resulted in a moderate concern for increased cancer risk (7.9 extra cases per ten thousand people), which is similar to cancer risks posed if the clams are purchased from the grocery store or collected from an uncontaminated location (2.2 extra cases per ten thousand people). Risks are higher for consumption of softshell clams than for other clam species. Arsenic exposure can be reduced by removing the siphon from softshell clams prior to consumption. Shellfish are a healthy protein source in a balanced diet.

3. **ATSDR cannot conclude whether site-related metals are present in Gastineau Channel sediments or crabs at levels that could harm people's health.**

   Basis for Conclusion. ATSDR does not have enough information to make a conclusion. Metals levels in the sediment of Gastineau Channel below the low tide line off Sandy and Red beaches have not been well characterized. Insufficient numbers of Dungeness crab samples were collected to evaluate their safety as a food item. However, the limited data for metals in crab do not show a health hazard for human consumption.

4. **Conclusion 4. ATSDR cannot conclude if the levels of contamination in the past were harmful to tribal members who lived in Indian Village at the southeast edge of Douglas Alaska, prior to its burning and destruction in 1962.**

   Basis for Conclusion. We do not have enough information to conclude whether past site-related chemical contaminants in soil, sediment, drinking water or shellfish could harm people's health. Because contaminants from mining, including metals and cyanide, were not characterized in the environment during that era, we will never have the information to decide whether exposures from the mine may have harmed people's health.

5. **ATSDR cannot conclude whether metals or cyanide concentrated during mining operations in the upland area soils of the historical mine area can harm people recreating in the area. ATSDR cannot conclude if metals in deep beach sediment (more than three feet deep) are harmful to recreational miners who dig deep holes in tailings on the beach.**

   Basis for Conclusion. Surface soil has not been characterized in upland areas of mining operations, except in two tailing pile areas at the former Mexican Mine that have been capped and annually monitored. Sandy and Red Beach sediment has not been characterized below three feet deep.

6. **Touching or swallowing small amounts of metals in sand while walking, playing, recreating, or harvesting shellfish on Sandy or Red Beaches or Savikko Park is not expected to harm people.**

   Basis for Conclusion. ATSDR evaluated several reports for information on the levels of metals found in soil and sediment at Sandy and Red Beaches and at Savikko Park. ATSDR compared the metal levels in sediment to health-based comparison values for soil to determine whether they pose a potential health hazard to people who walk or play on the beaches. Metal levels in beach sediment or sand were similar to, or even lower than, metals levels in sediment from unimpacted background areas of southeast Alaska. The metals levels in sediment were below the health-based screening criteria, indicating that the sediments do not pose a health hazard.

Next Steps

The City and Borough of Juneau and the Douglas Indian Association should

- participate in a shellfish monitoring program, and provide the public with current and easily available information about PST conditions at monitored beaches, and
- post warnings about Paralytic Shellfish Poisoning in areas that are often unsafe for shellfish harvesting and consumption.

The City and Borough of Juneau, the Historical Society, and/or the Alaska Department of Environmental Conservation should

- evaluate if the upland areas of the site have been sufficiently characterized to protect public health, particularly if plans to further develop the area as an historic park come to fruition,
- post signs advising people not to dig deep holes at the beach. Evaluate whether education activities should be conducted to inform recreational miners about the potential hazards associated with re-mining historical tailings at depths that have not been characterized (i.e., greater than 3 feet deep), and
- consider designing and implementing a plan to characterize metals contamination in Gastineau Channel sediment and crabs, in areas where tribal and community members most commonly harvest Dungeness crabs. This project would inform public safety. Crabs are mobile animals and metals in edible tissues may come from background, multiple historical mines, or other sources of contamination in the area.

What can Tribal members and the public do to protect their health?

Beaches where shellfish are collected commercially are highly regulated and routinely tested for PSTs. Consider buying shellfish from the grocery store.

If you collect and eat shellfish from non-commercial area beaches, you can take these actions to reduce your risk:

- Know there is always some degree of risk associated with eating shellfish. Watch for early symptoms of PSP after eating shellfish and get medical attention immediately if any symptoms develop. If possible, save a sample of the suspected food item for PST testing (but label it unsafe to eat).
- Avoid harvesting shellfish when PST levels are above Alaska's regulatory safety limit of 80 µg saxitoxin/g tissue. Shellfish toxins are often highly localized. Do not assume that your favorite beach is safe simply because a nearby one has been tested.
- Contact your local Tribal government, and/or check the SEATOR website at http://www.seator.org/data, for the latest plankton and toxin results from your community's monitored beach.
- Avoid harvesting butter clams, which commonly have PST levels above Alaska's regulatory safety limit.
- Do not eat the internal organs from crabs and shrimp. Remove internal organs before cooking the meat.

How Tribal members and the public can reduce metal exposures.

- Enjoy moderate consumption of shellfish from the site, as part of a varied, balanced and healthy diet. Collect crab from many different locations and eat in moderate amounts as part of a varied, balanced, and healthy diet. Protect yourself from PSTs (see above).
- Avoid serving sea cucumbers to children under the age of six, to avoid potential stomach upset from copper exposure. Or, feed your children only a very small serving of sea cucumber at a time (less than 2 ounces).

- Reduce exposure to inorganic arsenic by choosing softshell clams less often than other clam species, and/or removing the siphon from softshell clams before consumption. (Softshell clams are also sometimes referred to as steamer clams, nannynose, sand gaper, or long-necked clam.) They can contain higher amounts of toxic inorganic arsenic than other local clam species do.
- Recreational miners should be aware that mercury, cyanide, arsenic, and other metals may be concentrated in deep soil and sediment at the beach, which have not been characterized. As a precaution, wear gloves, a long-sleeved shirt, long pants, and sturdy enclosed shoes to minimize skin exposure to tailings. After handling beach sediment from deeper than three feet, wash your hands thoroughly before eating, drinking, or smoking. Remove soiled shoes and outer clothing before entering your car or home.
- Recreational users of upland areas of the historical mine should be aware that mercury, cyanide, arsenic, and other metals may be present in surface soil, which have not been characterized except near two tailing piles (which have been capped and are annually monitored; see Figure 6). Contamination may be present near old building foundations and mining equipment. If you play in the soil or touch historical mine debris, wash your hands thoroughly before eating, drinking, or smoking. Remove your shoes and wash dog's paws before entering your home, to avoid potentially tracking contaminated soil into your home.
- Tribal and community members should remove shoes and wash dog's feet after playing or walking on the beach, to minimize the tracking of site soil and sediments into the home.

Public Health Action Plan

- ATSDR will discuss findings of this public health assessment with the Douglas Indian Association, the ADEC, and the CBJ.
- ATSDR will accept public comments on this draft public health assessment for at least 90 days and will incorporate public comments and our responses into the final version of the public health assessment.
- ATSDR will hold a community meeting to discuss findings of the report with tribal members and the public.
- ATSDR will continue to provide public health input and technical assistance to interagency workgroups addressing harmful algal blooms in Alaska.

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If you have questions or comments, call Rhonda Kaetzel, ATSDR Region 10 Director, at 206-553-0530 or our toll-free number at 1-800-CDC-INFO (1-800- 232-4636) and ask for information on the "Former Treadwell Mine, Sandy and Red Beaches, Douglas Alaska" site.

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Appendices

Appendix A. ATSDR Community Engagement with the Tribe and Community

After accepting the petition to ATSDR in May 2019, ATSDR traveled to Juneau in July of 2019 to meet with the Douglas Indian Association (DIA) tribal council. ATSDR described the health assessment process and listened to the tribal council's concerns and expectations about our work to assess the potential health risks from the former Treadwell Mine Complex. The DIA tribal council was specifically concerned about potential exposures from direct contact or consumption of seafoods containing methyl mercury, inorganic arsenic, or lead contaminants from the former Treadwell Mine Complex, which was composed of four different mines including the Treadwell, Ready Bullion, Mexican and 700-Foot Mines. ATSDR conducted qualitative in-depth interviews with nine local Alaska Native individuals in Juneau, Alaska on February 27–28, 2020. The purpose was to learn about the tribe's relationship with the mine both historically and currently. We listened to information about traditional, historical, and current tribal use of the area and practices of shellfish harvest and consumption from the beaches on the Gastineau Channel near the former mines. DIA staff reviewed this summary for accuracy and representation of the conversations heard. ATSDR met monthly with DIA's environmental staff until the project was delayed due to COVID-19; calls resumed in January 2021.

ATSDR also met with the State of Alaska and City and Borough of Juneau to understand their outreach to the community regarding the mine.

The following is a summary of the conversations we have had with the tribal council and tribal members. In addition to the tribal council members, ATSDR would like to thank all the elders who generously shared their time, patience, and stories with us during in-depth interviews.

Conversations were guided to help ATSDR understand their memories and knowledge of the historical Tlingit villages in Douglas and Juneau, their use of the beach and shellfish near the Treadwell Mine complex, and their past and current use of the former village site near the Sandy Beach area. ATSDR is using this information to better understand potential exposures of tribal members to mining contaminants from the Treadwell Mine complex, and the potential health impacts of those exposures. While the last gold mine in the complex closed in 1922, the site's legacy as a potential contamination source is a continuing concern to DIA tribal members.

Alaska Natives have a deep understanding of the land and the environment that has been developed over thousands of years. The Tlingit relied heavily on seafood which made up the core of their diet. The traditional Tlingit economy was based on fishing, and salmon was their main source of food. The Tlingit are skilled fishers, traders and hunters who are brought up to respect all things, including the land, plants, animals, rocks, and water. The harvesting and preparation of traditional foods has an importance to Alaska Natives that extends far beyond caloric intake and nutritive needs. Gathering and eating traditional foods is "…who we are. It is our culture; it is in our DNA". Another elder put it this way, "Our life is inside of our foods". Harvesting and preparing foods is a community event that involves every person in the tribe; everyone has a job to do. The men would harvest the animals, the women would clean, preserve, and prepare the food, and children would have support roles from the time they could walk.

Alaska Natives have profound environmental ethics. They believe that creatures have just as much right to be here as people do. An elder explained that the harm from contamination of the environment extends beyond the physical health of people. "The contamination may not have done anything to any human being, but it has done a lot to the natural resources." Some resources that used to be plentiful are no longer in the area. Damage to the natural world includes damage to the Spirit, of which Alaska Natives are a part. The damage to the Spirit is more damaging than the contamination itself.

Traditional Food Harvesting Practices of Tribal members from The Douglas Indian Association. Local Tlingit clans, the *T'aaku Kwáan (Taku) and A'akw Kwáan (Auke),* have occupied the Douglas and Juneau area for time immemorial. During the summer months, tribal members would migrate south to the Taku River. They would harvest salmon, seals, and shellfish lower in the river and then go upriver to fish, hunt land mammals (deer, moose, goat, bear), gather greens and berries, and preserve the harvest. One tribal member referred to an 'old-fashioned' crab trap made to be used in the rivers. Dungeness crabs like to be near freshwater sources.

The rest of the year they lived on or traded their harvest and continued to fish or collect shellfish in the surrounding areas of Douglas and Juneau. These activities still occur, though less so than in the past. Everyone interviewed said that sharing and trading of resources remains an integral component of Alaska Native life. Tribal members take care of each other, and always care for and share with elders. Everyone will trade what they have for other things of value. For example, fresh shellfish may be traded for a cedar hat, or for grocery store staples.

The entire length of the Taku River, where they gathered food, is sacred to Tribal members. Some families fished for trade and bartered their harvest among other Alaska Natives as well as immigrants coming into Alaska. They also mentioned going to different places by boat or trading for seafood with relatives from Hoonah, Angoon, Kake, or Sitka.

"The tide is out, and the table is set." Tribal members have collected shellfish from numerous locations in the past. There is no record of how use of the shoreline near the mine changed after the mine started in 1891, or if tribal members shifted their harvesting locations. Several elders described going down to the beach to collect shellfish all along Gastineau Channel near what is now the city of downtown Juneau, to the north end of Douglas Island, north or south along the roads, and near the mines.

Many tribal members stated that cockles and gumboots were their favorite shellfish. They would harvest crab (dungeness, king, tanner), clams (butter, littleneck), cockles, and mussels. Sometimes they could also harvest and eat gumboots (lady slipper), black chiton, geoduck, snails, sea urchin, or shrimp. They would smoke or preserve shellfish in hooligan oil or seal oil. Crab is always eaten fresh. Oysters were not collected in the Juneau area; they were more common in the Sitka area.

Collecting shellfish near the former mines. While each tribal member reported getting shellfish from different areas, one elder recalled as a young boy living at the Douglas Indian Village, that "everyone used to go clamming and crabbing there at the village site [near the mine area]." He recalled collecting clams at the beach before the village burned, and that wintertime was for clamming and crabbing. "They would cook the clams on a flat rock after heating it up at the edge of a fire," he said. "There was another beach on the other side of the Glory Hole to collect shells from; there were huge snails in one area."

One elder noted that her Auntie used to pick mussels there [Sandy Beach], but she stopped when the elder was a teenager because the water had gotten too polluted. Other elders stated that there were no longer enough clams or cockles, or that they saw evidence that the shellfish were not healthy. The Sandy Beach area was never a primary source of food for the Douglas tribes, but it may have been one of many sources. None of the interviewees currently harvest shellfish from Sandy Beach because of concerns about contamination.

Fishing, crabbing and other subsistence hunting near the former mines. Tribal fishing families passed down their fishing boats and fishing and shell fishing gear. In the 1940s and 1950s, the men from the tribe would gillnet and setnet for salmon 24 hours a day, seven days a week, all summer long. Herring and herring eggs are also important traditional foods that are now very scarce in the Sandy Beach area and in Southeast Alaska. In the past needlefish, tomcod and sardines also used to be in the Douglas area but are not found anymore. Fishers harvested salmon, halibut, flounder, dolly varden, and other marine fish for miles around the Juneau and Douglas area. One elder recalled catching a king salmon under the bridge that connects Juneau to Douglas Island in 1972.

Fishers leaving the Gastineau Channel dropped crab pots offshore, sometimes near the former Treadwell Mine Complex. One elder stated "Sandy Beach is not a major collection area [for crab] and never has been. It is just an area of convenience." ATSDR noticed crab pots in the water offshore from Sandy and Red Beaches during a site visit, though it is unclear who dropped those pots. One elder was not sure it was Tribal members. Others have seen this as well, so someone is collecting crab near Sandy and Red Beaches. One elder that is a commercial fisher questioned the significance of contaminant levels found in crab and sediment. He claimed that crabs were migratory, and that sediment moved around a lot and fluctuated with the tide. One elder mentioned "even before the testing [in 2014], things started tasting different." Another mentioned that the fish became mushy and bad, and the meat would fall off the fish on the drying rack in the late 1990s. Juneau is one of the top destinations for U.S. cruise ships, which cause some environmental problems. Ships contribute to ambient underwater noise levels, which can significantly impact marine life in the channel.

Seals were also traditionally hunted. Fortunately, seal populations in the Juneau/Douglas area have remained stable. Products derived from seals include oil, meat, and skins. Seal oil is a popular condiment and preservative used by the Tlingit people. The Tlingit lifestyle also involved knowing about migrating and local birds that provide foods; seagull eggs and ducks were also collected. The men also hunted deer and mountain goats in the Taku area.

Tribal members harvested plants for both food and medicine. Seaweed used to be collected near the mine and nearby areas, but that is not done any more. Black seaweed was best collected in winter at low tide and at a certain length. Red seaweed was collected in spring. Others mentioned collecting sea ribbons, “Tlingit asparagus”, and goose tongue. Kelp bulbs were pickled. Goose tongue grew on beaches during the spring. One elder talked about a system to channel water onto cedar planks to rinse and clean the seaweed; then the seaweed was sprayed with cockle steam-water to impart a nice flavor. Kake, Yakutat, Hoonah and Angoon are good places to collect seaweed these days.

Blueberries and salmonberries were (and are) commonly collected, but not from the mine area. Devil’s club is used to make medicines. Tribal members also mentioned harvesting rhubarb, Indian celery, skunk cabbage, strawberries, and Labrador tea. One member asked if it was safe to collect berries from the mine area.

Permit rules in the 1970s changed access to food for Southeast Alaska tribes. The state started permitting commercial fisheries in the 1970s. Almost every tribal member talked about the profound impact this had on the ability of Southeast Alaska Natives to fish or shellfish for traditional foods. In the 1960s about half the commercial fishery was Alaska Native. One tribal elder said that after permitting started, Native commercial fishing in southeast Alaska was virtually wiped out. To determine who qualified to receive a fishing permit, a point system was established to document Historical Use. If a person had not been fishing in the area for the past five years, they did not qualify for a commercial permit. Another elder mentioned losing the opportunity to obtain a permit because there was not a waiver for military service [during the Vietnam war]. Entry into commercial fishing in southeast Alaska is now extremely expensive. Much of the commercial fishing in the area is done by people from outside Alaska.

The State of Alaska Department of Fish and Game (ADFG) established rules about when, what, where and how tribes can harvest seafood. A boat is needed to access locations that are now open to Alaska Natives for subsistence use. A rural preference in the State of Alaska’s constitution makes it difficult for Natives in urban areas to access traditional foods. The foods that elders grew up with have now become delicacies. Tribal members are concerned that overharvest of seafood resources and medicinal plants like devil’s club is occurring, by people that aren’t Alaska Native.

Use of the beaches near the former mines. The sand on Sandy Beach is composed of mine tailings which have been deposited on top of the rocky shoreline common in the area. The beach is large, the sand is fine, and access is open and easy. The beach is inviting and is used by families, tribe members, and the public for beachcombing, picnics, dog walking, beach sports, and a variety of other uses. Children dig in the sand, make sandcastles, and bury each other in the sand, as at any other beach. Sandy Beach is a popular recreational area, especially in the summer. The beaches on the other side of the cave-in below the Glory Hole can be accessed only at low tide, or by upland trails.

In recent times, tribal members have observed recreational gold miners digging deep holes in the sand and soil on/near Sandy Beach. The holes are in the historical mine tailings, and they can be about 6 feet deep. Recreational mining is a completed exposure pathway to deeper soil that has not been tested (to our knowledge) for mine contamination.

Memories of the former Treadwell Mine Complex. The Treadwell Mine Complex is composed of four separate historic mines that are located on the uplands just above Sandy and Red Beaches. The mines historically dug tunnels beneath the uplands, with myriad interconnections. In 1917 there was seawater intrusion and a catastrophic tunnel collapse in three of the mines, which created a pond-like feature near the beach that is sometimes mistakenly called the Glory Hole. Three of the four mines were closed immediately after that disaster occurred; the Ready Bullion mine closed permanently in 1922.

One elder recalled that after the mine complex shut down, the company hired a night watchman to look after the property. That person took local children on tours of the old mine, and he encouraged them to play with liquid mercury. The children would use the mercury to shine coins. Another elder stated that in the 1940s, there was so much elemental (liquid) mercury in the sand at Sandy Beach that children could pick it up with magnets. The children would gather the mercury with magnets and shine coins with it. Another elder recalled that there were large rats associated with the old mine. She used to feed them because she thought they were puppies.

The mine used a lot of coal, and there was a lot of coal left at the site after the mine was closed. After asking permission, the village used the coal to heat their wood stoves. One elder recounted that the evergreen trees in the upland area behind the village street turned brown, possibly due to the smoke from the coal, or from chemicals the mine used.

Another tribal member who grew up in Douglas said that children would play in the old mine area. They would explore the old adits. They risked encountering a number of chemical, physical and biological hazards, including collapses and landslides, accumulation of toxic gases, and animals like bats.

Historical Trauma. The Native people of Douglas suffered significant historical trauma, which continues to impact the health and well-being of the tribe. When the elders we interviewed were children, they were subjected to racial discrimination. In Douglas, all the Natives lived on one street at the edge of town, called “Indian Village”. There was no running water or electricity. Natives were considered third-class citizens, and they were not welcome in the broader community of Douglas. Before Statehood, Douglas had a U.S. Marshall assigned to it. By law, Alaska Natives were not allowed to meet as a group. The law was meant to keep them from organizing.

In the early 1960s, the City of Douglas established a law that if a residence was unoccupied for greater than thirty days, the house was considered unoccupied, and it was condemned. Of course, the tribal members were gone all summer to their subsistence camps. In 1962, while the Natives were at their summer camp, their houses were all burned by the city, one by one, as described by an elder who was a young boy at the time. This was an act of terrorism, and everyone in the community was afraid to talk about it. Natives in Douglas dispersed to different parts of Southeast Alaska after their houses were burned. They were never to live together again as a geographically cohesive group. There are now only a few elders left from the old village. “They all dispersed, and now they’re all gone.”

This historical trauma is important to mention in this public health assessment appendix because it contributed to the diminishment of a vibrant, healthy way of life that included community and environmental values and a connection to traditional food sources that had sustained tribal members for hundreds if not thousands of years. “Everything is connected.”

Tribal members are concerned about multiple contamination sources. There are historic mining areas on the Juneau side of the Gastineau channel. Exposure to contamination from these mines is also of concern. Other potential sources of contamination of the Gastineau Channel include the unlined city dump near the airport (which is right by a river that drains to the channel), chemical and radiological contamination from Russia and Japan, and gray-water discharge from cruise ships.

Paralytic shellfish poisoning (PSP) is a known hazard associated with eating shellfish collected from non-commercial beaches, which are generally not tested for PSP. One elder we interviewed lost a close relative to PSP after eating cockles collected from a southeast Alaska beach.

Several elders expressed concern about a perceived cancer epidemic among Alaska Native people. One interviewee said that the incidence of tumors on salmon seems to be increasing.

DIA also expressed concern about a proposed re-development of the Treadwell Mine complex area. The Treadwell Mine Society has completed a memorandum of understanding with the City and Borough of Juneau to establish terms for a recreational area with interpretive signs about the history of the mines. The project can only occur if funding is secured for the project. The tribe is concerned that if the mining area is cleared and developed for recreational use, it might establish new exposure pathways to mine contaminants and/or increase the number of people who are exposed to mine contaminants.

Appendix B Frequently Asked Questions and Answers

At the request of the tribe, ATSDR answers questions ATSDR received during the development of this public health assessment in Appendix B. Most questions we were able to answer; however, some questions were outside the purview of this report. Some questions may or may not have existing scientific evidence to provide an answer.

Former Treadwell Mine Complex activities

1. What is the former Treadwell Mine Complex?

The former Treadwell Mine Complex is a historical mining area located south of Douglas, Alaska on the Gastineau Channel opposite of Juneau, Alaska. From 1891 until 1917, four gold mines operated on the eastern side of Douglas Island along Gastineau Channel from south to north: Ready Bullion Mine, Mexican Mine, 700-Foot Mine, and Treadwell Mine. Three of the mines closed following a large cave-in in 1917, while the Ready Bullion Mine closed permanently in 1922. Together, the four mines are known as the former Treadwell Mine Complex.

2. What kind of mining occurred at the mines?

Gold-bearing ore (soil and rock) was removed from the ground by pit mining and underground tunneling. Miners pulverized gold-bearing rocks with stamp mills to the size of sand, then spread them over liquid mercury to remove gold. Cyanide was also used to remove gold from ore. Collectively, the mines produced more than 20 million tons of ore during their operating years.

3. What are tailings?

Tailings are the sand-like material left over from the process of separating the gold from the ore. Tailings can contain residues of chemicals that were used to extract the gold, such as cyanide or mercury. Tailings can also contain other metals that were naturally in the ore, that have become more concentrated.

4. What contaminants were released during mining operations?

The former Treadwell Mine Complex produced two main types of waste: processed ore tailings and chemical wastes. Tailings from the mining operations likely contained mercury or cyanide from ore processing, and metals contained in the original ore, such as arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, and silver. The current location and form of these metals is mostly unknown. Leftover tailings extend continuously on the beaches for about 8,000 feet, southeast from Sandy Beach to the Ready Bullion mine at Red Beach. There are also two tailings piles containing waste rock from cyanide processing; one is near the beach while the other is located in uplands (see Figure 6). These disposal areas, referred to as "cyanide tailing piles" on historical maps, have been capped and re-vegetated to prevent human exposures to mining wastes.

Sandy and Red Beaches on Gastineau Channel, near the former Treadwell Mine Complex

5. Where are Sandy and Red Beaches and what kind of beaches are they?

Sandy Beach begins southeast of the Douglas Harbor at Savikko Park, and it extends southeast to the cave-in below the Glory Hole (Figure 2). Red Beach begins at the cave-in and extends southeast below the 700-Foot Mine, the Mexican Mine, and the Ready Bullion Mine. Both beaches are composed of sandy tailings from historical mining operations at the former Treadwell Mine Complex.

6. Which metals have been measured at Sandy and Red Beaches?

In initial investigations, regulators have analyzed for a wide range of 18 metals in beach sediment (see Table C5 in Appendix C for the full list). All of these metals except two were detected, but at concentrations similar to those found in sediment from unimpacted background areas in southeast Alaska. Antimony and thallium were the two metals that were not detected. Mineral rocks and soil in Alaska naturally contain a certain amount of metals, which are in the earth's crust. Based on the limited data available for review, we did not see a big difference in concentrations from one beach to another.

7. Is there cyanide in the sand at Sandy and Red Beaches?

Yes. Small amounts of cyanide were measured in two sediment samples, at levels similar to those found in background samples. Small amounts of cyanide are present naturally in soil and sediment. Cyanide levels in the sand were far below those associated with possible health effects.

8. Is it safe for children to play on the beach, and in the sand at Savikko Park?

Yes. ATSDR determined that chemicals are not in beach or park sand at levels that cause health concern. Lead is present in the beach and park sand at levels similar to unaffected areas. To avoid child exposures to chemicals, we recommend washing hands after play or before eating, and preventing sand from entering the home.

9. Can metals in the sand go through your skin?

No. Skin absorption is not an important exposure pathway for metals in soil. The most important exposure pathway for chemicals in sand is accidentally swallowing small amounts of the sand. ATSDR recommends that people wash their hands thoroughly with soap and water before they eat, drink or smoke, especially after playing in soil, sand, or sediment.

10. Is my family safe if we track sand from the beach or park of the former mine complex into my car or home?

Yes. However, it is always good to limit the amount of sand and dirt that you bring in from outdoors. ATSDR recommends that you remove your shoes when you enter your car or home. Likewise, if your dog's paws are dirty after a day at the beach, it is good to wipe them clean before your dog enters your car or home.

11. Is there gold at Sandy and Red Beaches that we can dig for? Is it safe?

ATSDR does not know whether there is gold or other valuable metals in the leftover tailings from the former Treadwell Mining Complex. ATSDR did not find any information about contaminant levels in sediment below three feet deep, so we don't know whether digging deeper holes is safe.

12. Is a recreational miner digging up to six feet into the sediment at the beach more at risk?

ATSDR did not find any information about contaminant levels in sediment below three feet deep. Since the deeper sediment has not been characterized, we don't know whether digging deeper holes is safe.

13. When I was young, there was liquid mercury you could pick up on the beach. Is there still liquid mercury at the beach?

None of the formal investigations at the site have encountered liquid mercury in soil, sand, or sediment. We don't know if any liquid mercury might remain in deeper soil or sediment that has not been characterized, or if there are stray pockets of contamination that haven't been found. **Please be aware that liquid mercury is very dangerous to your health.** If you come across liquid mercury, do not touch it. Please notify the Alaska Department of Environmental Conservation immediately if you ever encounter liquid mercury, so it can be cleaned up and safely disposed of (see https://dec.alaska.gov/spar/ppr/spill-information/reporting for reporting instructions.)

14. What did they do with the dredge materials from Douglas Harbor? Were there contaminants in the Douglas Harbor dredge materials?

In 1962, the Douglas Harbor Basin was dredged to 12 ft below the mean lower low water (MLLW) level and an entrance breakwater was constructed. The placement of dredge material on Douglas Island provided a foundation for the roadways, parks, and recreational areas known today as Savikko Park [Newfields 2009]. Douglas Harbor sediments are contaminated with mercury which is thought to have originated from the Treadwell Mine Complex, with subsequent northward movement by long-shore currents. The U.S. Army Corps of Engineers maintains and periodically dredges Douglas Harbor. They historically deposited dredged materials into the Gastineau Channel in an unconfined manner [Newfields 2009]. In 2016, the Corps dredged the harbor to 14 ft below MLLW, disposed dredged materials in the Gastineau Channel, and placed a sand cap over the location [2017 report]. These dredge materials contained methyl mercury.

Shellfish found on or near Sandy or Red Beaches on Gastineau Channel, near the former Treadwell Mine Complex

15. What kind of shellfish can be found on the beaches near the former mines?

When researchers collected shellfish from the beaches for characterization in 2014, they found mussels, clams, cockles, and sea cucumbers at low tide. Dungeness crabs are in the deeper waters of Gastineau Channel. Shellfish are not overly abundant on Sandy Beach or Red Beach, and there probably aren't enough shellfish available for many people to eat lots of them. CBJ reported to ATSDR and tribal representatives that divers from the City and Borough of Juneau did not find an abundance of shellfish in the water along the mines, except for scallops.

16. Are shellfish safe to eat? I heard they can make you throw up or even kill you.

The surface water and shellfish from Sandy and Red Beaches are not tested for biotoxins or bacteria. If shellfish are harvested from site beaches, it is important to know that clams, mussels, cockles, and other shellfish may contain toxins from single-celled algae or bacteria that if ingested, can make you sick or even cause death. Many of these toxins cannot be destroyed by cooking or freezing. You can find information about recent tests on the Juneau side of the channel at a website maintained by the Southeast Alaska Tribal Ocean Research partnership (SEATOR) at https://www.seator.org/data/. Toxin levels can vary from location to location, and can change quickly over time, so test results from Juneau may serve as a warning (if high) but NOT as an indicator of safety in Douglas (if low). In general, there are four kinds of sickness that you can get from eating shellfish if they contain toxins. These are all described at the SEATOR website at https://www.seator.org/resources/.

- **Paralytic Shellfish Poisoning (PSP)**. PSP is a serious illness caused by eating shellfish contaminated with dinoflagellate algae from the genus *Alexandrium* that produce harmful saxitoxins. Get medical help immediately if you experience the following symptoms after eating shellfish: nausea, vomiting, diarrhea, abdominal pain; tingling or burning lips, gums, tongue, face neck arms, legs, and toes; shortness of breath; dry mouth; a choking feeling; confused or slurred speech; and lack of coordination. In rare instances, PSP may cause death. The closest location where shellfish are consistently tested for Paralytic Shellfish Toxins is at Point Louisa, north of Juneau. Butter clams at this location have PST above levels of concern year-round.
- **Diarrheic Shellfish Poisoning (DSP**). Diarrheic Shellfish Poisoning is caused by eating shellfish containing dinoflagellate algae from the genus *Dinophysis*. The algae produce a toxin that causes severe symptoms including nausea, vomiting, abdominal cramping, and diarrhea. These symptoms are not life-threatening, and patients recover in a few days.
- **Vibriosis (rare**). Vibriosis is an intestinal disease caused by small bacteria called vibrio. Vibrio are bacteria found in fish and shellfish living in saltwater and in rivers and streams where freshwater meets saltwater. The bacteria multiply in warm conditions, so fish and shellfish are more likely to be contaminated in the summer. Most cases occur from eating raw or undercooked fish or shellfish. Vibrio is destroyed by cooking shellfish to an internal temperature of 145°F for 15 seconds. Symptoms include diarrhea, abdominal

cramps, nausea, vomiting, headache, fever, and chills. Patients generally recover in two to three days. Only 12 cases in Southeast Alaska from 2005 to 2018 have been reported.

- **Amnesic Shellfish Poisoning (ASP**). Amnesic Shellfish Poisoning is another serious illness caused by eating shellfish contaminated with diatoms (single-celled algae) from the genus *Pseudo-nitzschia* that produce the harmful toxin, domoic acid. Domoic acid is a neurotoxin and can affect brain function.

17. Are shellfish from beaches contaminated with chemicals from the former mine complex?

ATSDR identified site-related data on metals and cyanide in clams, mussels, and cockles collected near the former mine complex in 2014 to determine if eating these could harm health. Very few samples of crab, sea cucumbers and snails were also collected during those projects. ATSDR found that the shellfish samples contained arsenic, cadmium, copper, lead, mercury, selenium, and cyanide at levels similar to non-industrial background areas of southeast Alaska. Copper and arsenic levels in the samples were similar to levels found in seafood from the grocery store.

18. Do shellfish collected from beaches near the former mine complex contain mining contaminants that can harm the health of my children?

Occasional intake of site-related metals or cyanide from shellfish consumption does not pose a health risk to most community members. However, copper levels in sea cucumbers may be high enough to cause acute stomach upset in young children under the age of six. Parents may not want to feed sea cucumbers to their young children for this reason.

19. Do cockles and mussels collected from beaches near the former mine complex contain mining contaminants that can harm my health if I eat them my whole life?

No. Cockles and mussels did not contain metals at levels that could harm your health over the long term. This was true for both the once-a-month ceremonial dietary scenario, and the traditional diet scenario.

20. Did clams collected from beaches near the former mine complex contain mining contaminants that can harm my health if I eat them my whole life?

Softshell clams can have higher amounts of the toxic form of arsenic in them than other types of clams and shellfish. Even though the arsenic levels in softshell clams were similar to those from uncontaminated “background” areas and the grocery store, consumption of them at a traditional diet rate poses a moderately elevated risk of cancer over your lifetime. You can reduce that risk by removing the siphon from softshell clams before you eat them, because the arsenic is concentrated in the siphon.

21. Are homeless people, documented to live on the former mine complex, at risk from eating shellfish at the beach?

When ATSDR assessed potential risks from eating shellfish at the beaches, we assumed that people might eat a lot of shellfish. Those assumptions will be protective for homeless people who might live at the site. Shellfish are not overly abundant on Sandy Beach, and there probably aren't enough shellfish available to ingest unsafe amounts of mining contaminants from them. However, homeless people are at risk of serious illness or death if they eat shellfish with high levels of PSTs, just like anyone else.

22. What is a traditional diet eaten by Native Alaskans in this area? Are we safe eating shellfish from the beaches for our traditional diet?

Elder DIA tribal members honored ATSDR staff by meeting with us to describe their traditional lifestyle and diet (see Appendix A). In this report, ATSDR evaluated a traditional diet when assessing shellfish safety. The Subsistence Division of the Alaska Department of Fish and Game (ADFG) performs detailed surveys of subsistence communities to quantify the amounts of each type of traditional food the community members eat. A subsistence survey was not available for Douglas or Juneau, which are not designated by ADFG as subsistence communities under Alaska law. ATSDR evaluated data from ADFG subsistence surveys for the communities of Hoonah, Angoon and Yakutat, and selected Hoonah subsistence harvest rates as a proxy for DIA tribal members. ATSDR found that consumption of shellfish from Sandy and Red Beaches would mostly be safe, even at Hoonah traditional diet rates over a lifetime. Softshell clams posed a moderate cancer risk from arsenic, that can be reduced by removing the siphon before eating it.

23. Did the mine kill all the shellfish? Is that why there are so few left?

ATSDR does not have information about historical environmental conditions in the mine area, historical abundance of shellfish, or potential causes of shellfish population decline. The current habitat at the beaches is sandy, from the mine tailings. Some shellfish species like blue mussels are more commonly found on rocky substrates [Newell 1989], so it is possible that the current habitat type just isn't ideal for them.

22. What kind of crab can be found in the Gastineau Channel near Sandy or Red Beaches? Are we safe eating crab harvested near the former mine complex?

Dungeness crabs are commonly harvested from the deeper waters of the Gastineau channel near Sandy and Red Beaches. ATSDR did not find sufficient data to characterize the safety of crab consumption with enough certainty. Based on the limited data available, we did not find a health risk from metal contamination. The good news is that the risk of Paralytic Shellfish Poisoning from eating crab can be avoided by discarding the organs or viscera before cooking the crab meat. We recommend eating crab harvested from multiple locations.

Exposures in the upland areas of the former Treadwell Mine Complex

23. Will the plan to expand recreational access to the former Treadwell Mine Complex by building a boardwalk, amphitheater, and playing field result in recreational exposures to mining contaminants? Could the activities release mining debris and contamination to the beach, that people can track home?

ATSDR could not find sufficient information about potential soil contamination in upland areas to answer this question. If surface soil contains mining contamination, people could be exposed to the contaminants by touching dirt, inhaling dust, or tracking contaminated dirt home on their shoes.

24. Can we safely eat berries or greens collected within the former Treadwell Mine complex?

ATSDR could not find sufficient information about potential surface soil contamination in upland areas to answer this question. People can wash berries and greens collected from the site to remove soil and dust from their surface, but it is sometimes difficult to remove all surface dirt from berries and greens.

25. What kind of cleanup actions have occurred at the former Treadwell Mine Complex?

The Mexican Mine has implemented institutional controls to prevent exposure at the two cyanide tailing piles. The lower cyanide tailings pile is located 50 feet upland from the high tide of Gastineau Channel. AJT Mining Properties, Inc. placed a stabilization cap of clean fill material over this pile in 2006. A similar cap was placed further upland on the upper cyanide tailings pile in 2008. The caps on these piles are inspected twice a year. A recent report commissioned by AJT in 2019 detected eight of nine metals and cyanide in a composite sample from the lower cap [Nortech 2019]. While arsenic was detected at a level (22.8 mg/kg) above ATSDR's comparison value (17 mg/kg), this level was considered to be similar to background and not of additional concern. The other contaminants were below ADEC's cleanup levels established to protect human health.

26. What is under the top layer of sediment at the beaches near the former Treadwell Mine Complex? Shouldn't they use cores to find out where the 'hot zones' are?

The sediment of the upper areas of Sandy Beach has been well characterized to a depth of three feet. ATSDR could not locate information for deeper sediments near the mine. There are few exposure pathways to deeper sediments other than reports of recreational miners. Testing or remediation may increase exposures by mobilizing contaminants. ADEC, the environmental regulator, decides if further sampling is needed to characterize deeper sediment.

Greater Juneau area questions

27. Are fish or crab from Gastineau Channel safe to eat?

ATSDR does not have enough information about contaminant levels in fish and crab from Gastineau Channel to answer this question.

28. Has the AJT mine near Upper Sheep Creek, across the channel from the former Treadwell Mine Complex, released contaminants?

The historical mine near Upper Sheep Creek is listed by ADEC as "Nowell Mine Old Mill" in their database, Hazard ID 26195. Investigations of this mine have included the upland mine area, the Sheep Creek Mine Portal, and the Alaska Gastineau Mine Tailings zone near the marine environment [Nortech 2013b, Nortech 2014]. The investigations found that arsenic, cadmium, chromium, lead, mercury, selenium, and silver were above ADEC cleanup levels in soil at the former Nowell Mill site. The Nowell Mill site is not easily accessible to the public. Contamination is on a steep, heavily vegetated slope, about 150 yards from the mine road up Sheep Creek valley [Nortech 2013b]. The site status is still "open" in the ADEC database; exposure to contamination is being managed with institutional controls (signage). Environmental contamination was not found in soil samples from the Alaska Gastineau Mine Tailings zone near the marine environment.

29. Does the AJT mine pose a health risk to walk or collect shellfish on the shoreline nearby?

No. As detailed in the answer to #28 above, environmental contamination from the Nowell Mine Old Mill site was only found in the upland area of the historic mine site, not in the shoreline area or marine environment.

30. Are there releases from the landfill at Lemon Creek? It is unlined and next to a river.

The landfill at Lemon Creek, now called the "Capitol Disposal Landfill" or CDL, is an unlined landfill serving the municipality of Juneau. The site property and surrounding area have been used as a waste disposal facility since at least the 1960s [SGS Engineers 2020]. Disposal of waste material and various types of debris was reportedly widespread and uncontrolled throughout the entire Lemon Creek region prior to the area's development. In more recent times, environmental control systems have been installed to control offsite migration of contaminants. These improvements include an active gas collection and control system and a leachate collection French drain system along segments of the landfill footprint. ADEC now administers the facility's permit, and the facility had routine inspection, monitoring, and reporting requirements. You can learn more here [accessed February 22, 2021]: https://dec.alaska.gov/Applications/EH/SWIMS/ModFacility.aspx?SiteId=438

31. Should we be concerned about radiation contamination from other countries?

No, there are currently no known radiation threats in Alaska. There are several federal programs to monitor for radiation occurrence in the U.S. environment. For example, the U.S. Environmental Protection Agency has a large network of air radiation monitors across the country, including some in Alaska. The U.S. Food and Drug Administration routinely measures radiation levels in commercial foods to assure a safe food supply. Additional testing of seafood for Fukushima-derived radiation after the 2011 nuclear accident has been performed by universities, research organizations, some Pacific states, and Canada. These researchers have found that there is minimal to no risk of seafood contamination from the Fukushima event. You can learn more here [accessed February 22, 2021]: http://dhss.alaska.gov/dph/Epi/eph/Pages/radiation/default.aspx

32. What do cruise ships dump into Gastineau Channel? I have seen them dump wastewater into the channel. What is in that water? The cruise ships dock across the channel from Sandy and Red Beaches.

Cruise ships are regulated by ADEC with the goal of preventing air pollution, non-compliant wastewater discharge, and observing oil pollution, sheens, and acidic discharge. ADEC has issued a general permit to large commercial passenger vessels for marine discharge of treated sewage, treated graywater, and other treated wastewater from large commercial passenger vessels [ADEC 2014a]. To discharge wastewater, large cruise ships must have a permit from ADEC's cruise ship program, process all water through an advanced wastewater treatment system, and sample discharged effluent twice a month. Limits are imposed on fecal coliform discharges; the limits are based on the Alaska water quality standard for consumption of raw mollusks.

Forty large cruise ships operated in Alaska in 2019. Those cruise ships completed 573 voyages in Alaska waters, with a total capacity of 1,258,570 passengers [ADEC 2019]. Of the forty cruise ships, 24 ships were authorized to discharge treated wastewater in Alaska, and 18 ships discharged treated wastewater and conducted sampling. Samples for the 2019 season were collected while a cruise ship was discharging in southeast Alaska, and the majority of samples were obtained in or near Juneau. Parameter exceedances were rare in sampled discharges; they occurred for fecal coliform, dissolved copper, ammonia, and one instance of low pH.

33. How many people from Douglas have contracted cancer?
Cancer is a complicated topic. There are over a hundred types of cancer, which are each technically a different disease. There are several sources of cancer incidence data for Alaska. The State of Alaska provides cancer incidence data by diagnosis year at the borough level, broken down into each anatomical site of cancer. You can find that information here:
http://dhss.alaska.gov/dph/Chronic/Pages/Publications/Default.aspx

In addition, the Alaska Native Tribal Health Consortium's Alaska Native Epidemiology Center maintains the Alaska Native tumor registry, to track cancer incidence specifically among Alaska Native people. You can learn more here: http://anthctoday.org/epicenter/antr.html#data

34. Does the wastewater treatment plant contaminate Gastineau Channel?

Juneau's first wastewater treatment facility for secondary treatment was built in the mid-1960s. Currently the City and Borough of Juneau brings wastewater to three treatment plants. These facilities remove solids and use microbes in secondary treatment to break down waste products. Disinfection inactivates any remaining pathogenic organisms before discharge to the channel. The closest wastewater system is the Juneau-Douglas treatment facility and the effluent pipe is less than a mile directly north of the site. This treatment plant is also permitted for three combined sewer overflows (CSO). The CSOs are used during high tide or major precipitation events and may result in direct release of untreated wastewater to the channel.

35. Should we be concerned about other mines in the area?

Gold and other minerals have been mined from both sides of Gastineau Channel, both currently and historically. Some mines have been investigated and some have not.

*Nowell Mine Old Mill***.** This site, listed in Alaska's contaminated site database, across the channel from the Treadwell Mine Complex, primarily affects upland areas and has not been found to contribute to contamination of the marine environment. For more details, please refer to the answers to questions #29 and #30 above.

*Thane Mine Dump Site aka Alaska Gastineau Mine Tailings***.** This site is listed in Alaska's contaminated site database. The tailings disposal site is on the tidal flats of the Juneau side of Gastineau Channel, and is the same site investigated below the Nowell Mine Old Mill. The site is located 4 miles southeast of Juneau on Thane Road. From about 1912 to 1920, approximately 11 million tons of milling residuals from nearby mines were deposited in the intertidal zone over an area of approximately 50 acres. In a 1987 site investigation, arsenic and lead were found to be elevated in sediment from one part of the site, and lead was elevated in mussels from the same area. In 2013, the current property owner AJT Properties contracted with Nortech consultants to characterize current conditions. Nortech conducted multi-incremental sampling of the mine tailings and collected samples of biota for analysis [Nortech 2013b]. Based on comparisons of metals in tailings to background soil concentrations in the area, and on a favorable cumulative risk evaluation, the ADEC approved the site for closure on June 12, 2014 [ADEC 2014b].

Appendix C Screening and Determination of Contaminants of Concern

ATSDR identified shellfish and sediment data available for review. Sediment data were compared with residential soil health-based comparison values to determine contaminants of concern. Based on the screening, other than lead, no chemicals were evaluated further in sediment. Lead is present at low concentrations and is discussed in Appendix D and in the text. Health-based comparison values are not available for biota consumption, so shellfish data were further analyzed. Exposure point concentrations of chemicals were determined for each shellfish species for use in health risk calculations (Appendix D).

Shellfish Data Evaluation.

In review of the shellfish samples from the site and background sites, ATSDR calculated exposure point concentrations for further evaluation in Appendix D.

Contaminant data. Table C1 lists the shellfish sampling events near the former Treadwell Mine Complex and other SE Alaskan areas as well the analytes measured that were considered in the development of this report. The shellfish data collected at the site in 2014 most likely represent current site conditions [Ridolfi 2014; ADEC 2015]. Background data used in the Salt Chuck mine remedial investigation represent current conditions [EPA 2018]. Though more dated, the USFWS data from the baseline study for Kensington Mine are also useful [Rudis 2001].

ATSDR rejected the following data:

- ATSDR rejected the two crab samples collected by ADEC. Both samples were found dead on the beach; they were not captured live in crab pots like the DIA/Ridolfi samples. Dead crab would have an unknown degree of desiccation which would impact “wet weight” meat concentrations of contaminants. One of the two samples was a graceful decorator crab, which is a small species not consumed by people. The rejection of these two samples did not affect hazard quotient calculations for arsenic or mercury in crab, which were both based on maximum levels measured in the DIA/Ridolfi samples. ADEC sample rejection did, however, lower an already small sample number for crab (from 4 to 2), and resulted in an inability to calculate risks from cadmium, copper, lead, and selenium in crab. Those elements were not analyzed in the DIA/Ridolfi samples.
- ATSDR did not use data from animals not reported to be eaten. These include ADEC samples for polychaetes, sea star, and spoon worm.
- ATSDR did not use the snail data because of the low sample size (n=1), and a very low level of consumption. However, ATSDR did use sea cucumber although its sample size was also small (n=2) because consumption levels were high enough to be documented by ADFG data.

Exposure point concentrations (EPCs) were determined for each species of shellfish and each chemical. ATSDR used ProUCL© to calculate the 95th upper confidence limit of the mean (95UCL) to use as the EPC if at least eight data points were available [ATSDR 2019]. If fewer than eight data points were available, the maximum detected concentration was used as the EPC. Table C2 describes the data available for each shellfish/chemical combination, and the derived EPC that was used in risk models.

Table C1. Shellfish sampling events at the Former Treadwell Mine Complex in Douglas and other locations in Southeast Alaska

Report	Species (number) and location	Analysis
Ridolfi for DIA [2014]	**Site samples:** Clam (1) at Douglas Marina Dungeness Crab (2) at Gastineau Channel off Red Beach	Mercury Methyl Mercury Arsenic Inorganic Arsenic
ADEC 2015 (sampled in 2014)	**Site samples:** Mussels (11) at Sandy and Red Beaches Soft shell clams (6) at Red Beach Clams, unspecified (3) Sandy and Red Beaches Cockles (4) Sea cucumbers (2) Crabs, dead (2), polychaete (2), snail (1), sea star (1), spoon worm (1) [data not used]	Arsenic Cadmium Copper Lead Mercury Selenium Cyanide (not in all samples)
EPA 2018 [Salt Chuck Mine Remedial Investigation]	**Background samples from Brown's Bay in SE Alaska:** Crab (5) Bivalve (26)	Metals Inorganic arsenic (crab and 5 bivalve samples)
Rudis 2001 [Proposed Kensington Mine Area Baseline Contaminants Study by USFWS]	**Background samples from Lynn Canal in SE Alaska:** Blue mussels (13 composite samples from 6 rocky outcrop locations, comprised of 14+ mussels each) near Sherman Creek and Sweeney Creek in Lynn Canal (north of Juneau)	Metals Cyanide

Table C2. Shellfish Data Review and Exposure Point Concentrations (EPCs) in mg/kg wet weight, Former Treadwell Mine Complex, Douglas, Alaska

Chemical	Clam EPC¶¶ mg/kg (Range) Number of Samples	Mussel EPC¶¶ mg/kg (Range) Number of Samples	Cockle EPC¶¶ mg/kg (Range) Number of Samples	Sea Cucumber EPC¶¶ mg/kg (Range) Number of Samples	Crab EPC¶¶ mg/kg (Range) Number of Samples
Arsenic, Total* (measured)	NC (1.1 – 3.3) n=10	NC (1.4 – 2.0) n=11	NC (0.86 – 1.6) n=4	NC (2.0 – 2.3) n=2	NC (3.19 – 9.07) n=2
Arsenic, Inorganic (measured)	NA (1.66) n=1	NA	NA	NA	**0.04¶¶** (0.024 – 0.04) n=2
Arsenic, Inorganic (calculated)	**1.22¶¶**[†] (0.56 – 1.68) n=10	**0.17¶¶**[‡] (0.14 – 0.20) n=11	**0.16¶¶**[‡] (0.086 – 0.16) n=4	**0.23¶¶**[‡] (0.20 – 0.23) n=2	NC
Cadmium	**0.11¶¶** (0.052 – 0.14) n=9	**0.44¶¶** (0.37 – 0.50) n=11	**0.069¶¶** (0.046 – 0.069) n=4	**0.24¶¶** (0.22 – 0.24) n=2	NA
Copper	**3.67¶¶** (0.64 – 4.1) n=9	**1.32¶¶** (1.1 – 1.4) n=11	**0.96¶¶** (0.43 – 0.96) n=4	**14¶¶** (7.4 – 14) n=2	NA
Lead	**0.34¶¶** (0.066 – 0.51) n=9	**0.17¶¶** (0.13 – 0.22) n=11	**0.16¶¶** (0.12 – 0.16) n=4	**1.4¶¶** (1.4 – 1.4) n=2	NA
Mercury, Total (measured)	NC (0.0096 – 0.0358) n=10	**0.019¶¶** (0.012 – 0.024) n=11	**0.028¶¶** (0.011 – 0.028) n=4	**0.041¶¶** (0.040 – 0.041) n=2	NC (0.049 – 0.062) (n=2)
Methyl Mercury (measured)	NA (0.0133) n=1	NA	NA	NA	**0.0385¶¶** (0.0322 – 0.0385) n=2
Methyl Mercury (calculated)	**0.023¶¶**[‡§] (0.0096 – 0.0358) n=10	NC	NC	NC	NC
Selenium	**1.33¶¶** (0.78 – 1.9) n=9	**1.5¶¶** (1.0 – 2.0) n=11	**1.3¶¶** (1.0 – 1.3) n=4	**1.1¶¶** (1.1 – 1.1) n=2	NA
Cyanide	**0.021¶¶** (<0.0157 – 0.021) n= 5[¶]	**0.0669¶¶** (0.0368 – 0.0864) n=11	NC** (0.0528) N=1	NA	NA

Source: ADEC 2015, Ridolfi 2014, 2016

NA – not available; NC – not calculated; EPC – exposure point concentration **(bolded and ¶¶)**

Notes: Used the maximum value unless more than eight samples available to calculate a 95 percent upper confidence limit (UCL) of the arithmetic mean. All contaminants were detected except one clam cyanide sample.

*****Total arsenic values were not used to evaluate toxicity. Forms of arsenic vary widely in their oral toxicity, with inorganic forms being most toxic. ATSDR has developed MRLs for inorganic arsenic; only the inorganic portion of "total arsenic" can be evaluated using ATSDR's oral MRLs. Thus, exposure point concentrations were not calculated (NC) for "total arsenic".

† For inorganic arsenic in clams, calculated UCL using ADEC (n=9) and Ridolfi (n=1) analyses. For ADEC samples, assumed that inorganic arsenic represented 51% of total arsenic based on ratio found in Ridolfi sample and corroborating evidence of elevated percentage of inorganic arsenic in background softshell clams in Browns Bay, Southeast Alaska. In Browns Bay, the percentage of total arsenic in the inorganic form was 19% in 6 softshell clam samples, while it was less than 1% in 4 samples of butterneck and littleneck clams [EPA 2018].

‡ Assumed that 10% of total arsenic in mussels, cockles and sea cucumbers was inorganic arsenic based on ATSDR 2007.

§Total mercury values were not used to evaluate toxicity. Forms of mercury vary widely in their toxicity. Most mercury within seafood is in the form of (organic) methyl mercury, which is more toxic than inorganic mercury. ATSDR used its oral MRL for methyl mercury, and protectively assumed that all measured mercury was in the methyl mercury form. Thus, no exposure point concentration was developed for "total mercury". For methyl mercury in clams, calculated UCL using methyl mercury from DIA sample (n=1) and assumed that total mercury was equal to methyl mercury from ADEC samples (n=9)
.

¶ Cyanide detected in 4 of 5 samples.

**EPC not calculated because cyanide analyzed for in only 1 sample, which is insufficient data for evaluation

Background shellfish data. Shellfish data for mussels, crab and clams from uncontaminated sites were also available for review. Background mussel samples were collected from Lynn Canal (north of the Juneau area) prior to establishing the Kensington Mine [Rudis 2001]. Background crab and clam samples were taken from Browns Bay as reported in the Salt Chuck Mine Superfund Site Remedial Investigation [EPA 2018]. In Browns Bay, the mean percentage of arsenic that was in the toxic inorganic form was higher in softshell clams (19%) than in butterneck or littleneck clams (0.6%) [EPA 2018].

Table C3. Range of Metals and Cyanide in Shellfish (mg/kg wet weight) from Uncontaminated Background areas in Southeast Alaska

Contaminant	Mussels* (n = 13)	Crab† (n=5)	Bivalves‡ (n=26)
Arsenic (total)	0.44 – 2.94	3.74 – 6.72	0.808 – 5.67
Cadmium	1.22 – 2.38	<0.00139 – 0.00754§	0.0474 – 0.59
Chromium	0.14 – 0.29	<0.0131 – 0.131¶	0.0762 – 2
Copper	0.80 – 1.48	1.88 – 3.24	0.228 – 5.65
Mercury (total)	<0.0101 – 0.0143**	0.0231 – 0.0361	<0.00088 – 0.0244**
Nickel	0.12 – 0.23	<0.00589 – 0.0823	0.115 – 1.47
Lead	0.09 – 0.21	0.235 – 0.412	n.d. (<0.0138 - <0.0305)
Zinc	7.40 – 13.00	32.9 – 40.2	4.76 – 17
Cyanide	0.17 – 0.32	NA	NA

* samples from Lynn Canal [Rudis 2001]
† samples from Browns Bay [EPA 2018]
‡ samples from Browns Bay [EPA 2018]. "Bivalves" includes three clam species (littleneck, butter and softshell) and cockles
§ Cadmium detected in 1 out of 5 crab samples
¶ Chromium and nickel detected in 2 out of 5 crab samples
** Mercury detected in 5 of 13 samples of mussels from Lynn canal, and 25 of 26 bivalve samples from Browns Bay
NA = Not Analyzed
n.d. = not detected

PST Data. ATSDR recognizes the significant public health risk posed by PSTs in coastal Alaska, so we find it important to mention during any discussion of shellfish safety. In Alaska, the Southeast Alaska Tribal Toxins (SEATT) partnership works to detect harmful algal blooms by sampling coastal waters for potentially harmful plankton species and testing shellfish for high levels of toxins. Samples are analyzed by the Sitka Tribe of Alaska Environmental Research Lab. In the Juneau area, shellfish are collected by the Central Council of Tlingit and Haida Indian Tribes of Alaska on a regular basis at Auke Bay Recreation Area (Pt. Louisa) and Amalga Harbor. Results are posted to the SEATOR website (www.seator.org) along with interpretive information for the public. Recent data are displayed and discussed in the main report (Figure 7).

Sediment Data Review and Screening

ATSDR identified site-specific and background data for review. Data were available for 18 metals including inorganic arsenic and methyl mercury as well as cyanide. The maximum value for each metal identified was screened using residential soil health-based comparison values. Based on the screening, no chemicals other than lead will be evaluated further. Lead is present in sediment at low concentrations and is discussed in Appendix D and in the text.

The site sediment data appeared to be consistent among the reports and had similar detection limits. The most comprehensive study of sediments used incremental sampling methodology [Nortech 2013a]. Tribal reports [Ridolfi 2014, 2016] provided additional data regarding methyl mercury and inorganic arsenic speciation. Sediment data from site-related beaches and background locations are in Table C5.

Table C4. Sediment sampling events at the Former Treadwell Mine Complex in Douglas and other sediment background locations, Southeast Alaska

Report	Type of Sample (number)	Depth	Location (number)	Analysis
Site Inspection for Treadwell Mine E&E 1991	Sediment composite (1)	3 inches	Sandy Beach	24 metals, cyanide
DIA & ADEC 2011	Sediment discrete (5)	15 cm	Sandy Beach (4), Red Beach (3)	Mercury Arsenic
Site Assessment Nortech 2013a	Decision Units (sediment and soil) using incremental sample methodology (8)	0.5-1.5' bgs 2-3' bgs	Savikko Park (4) Sandy Beach (4)	8 metals, cyanide (n=3)

Report	**Type of Sample (number)**	**Depth**	**Location (number)**	**Analysis**
Ridolfi 2014	Sediment composite (8)	6 inches	Sandy Beach Red Beach	Mercury Methyl mercury Arsenic Inorganic arsenic Lead
Ridolfi 2016	Sediment composite (8)	8 inches	Sandy Beach Red Beach	Mercury Methyl mercury Arsenic Inorganic arsenic
Site Inspection for Treadwell mine E&E EPA 1991	Background [soil] sample Grab sample (1)	NA	Soil sample, 1 mile north of Sandy Beach (near Crow Hill Road)	24 metals, cyanide
[Proposed] Kensington Mine Area, Baseline Contaminants Study (Rudis 2001)	Background sediment Grab sample (n=2)	Dredge	Lynn Canal near Sherman Creek and Sweeny Creek	8 metals, cyanide
Site Inspection for Thane Mine site E&E 1988	Background [soil] sample Grab sample (4)	NA	Near Juneau	

NA = Not Available

The location of the sediment samples collected from the site by DIA and their contractor Ridolfi are shown in Figure 8 of the main report. The following figures show locations of other site and background sediment samples.

Sediment evaluation is summarized as follows:

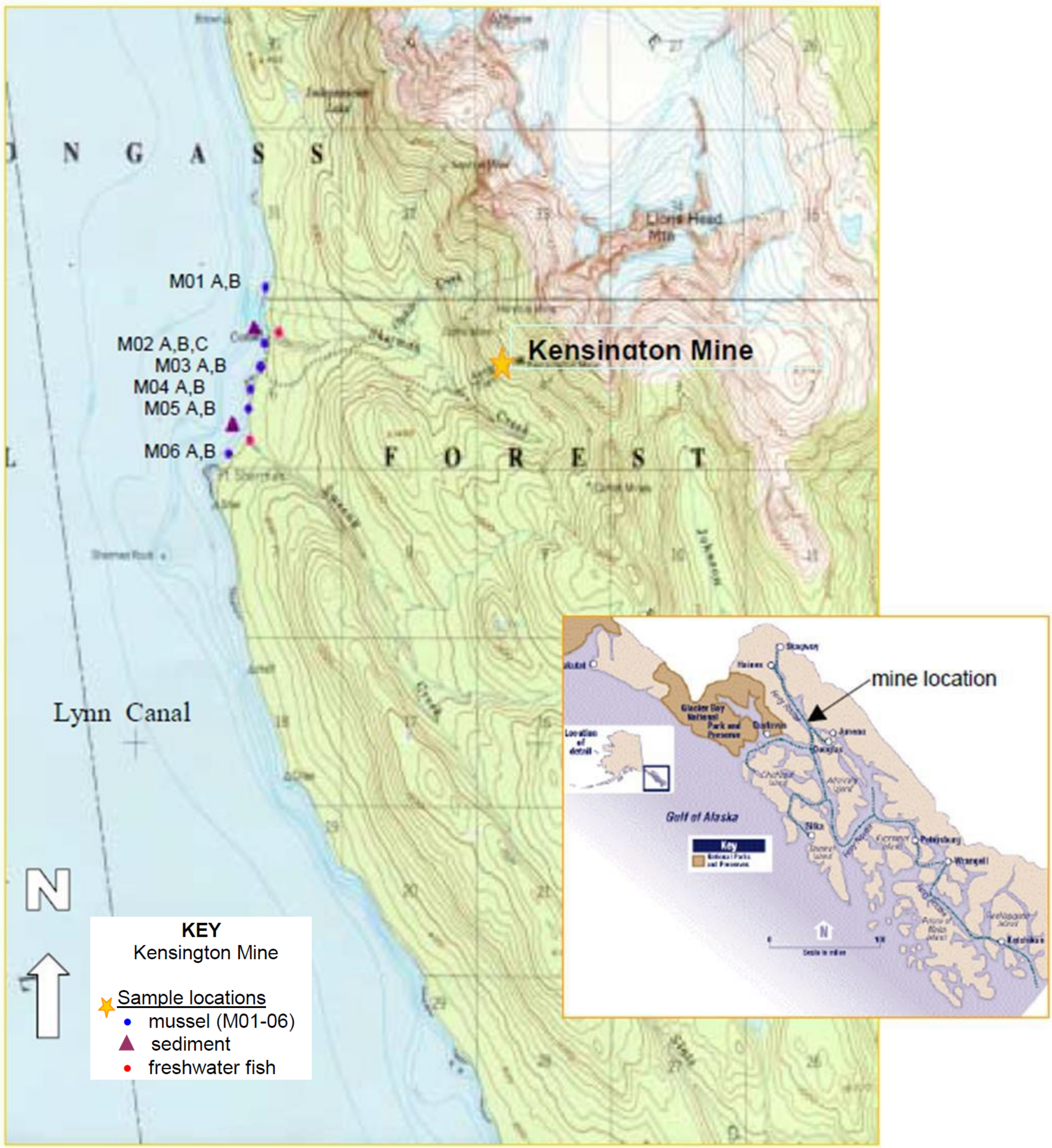
- The maximum concentrations of most metals in Sandy Beach sediments fell within or below the range of background concentrations, and below ATSDR CVs for residential soil.
- The maximum concentration of total chromium was above the ATSDR CV for hexavalent chromium, but well below the CV for trivalent chromium. Total chromium levels at the site were below background chromium concentrations. There is no known source of hexavalent chromium at the site.
- Methyl mercury maximum concentrations fell below the EPA RSLs for residential soil.

- The maximum lead concentration, while above the range of background concentrations, is not expected to result in an elevated blood lead level in exposed individuals.

Further evaluation of sediments is not warranted.

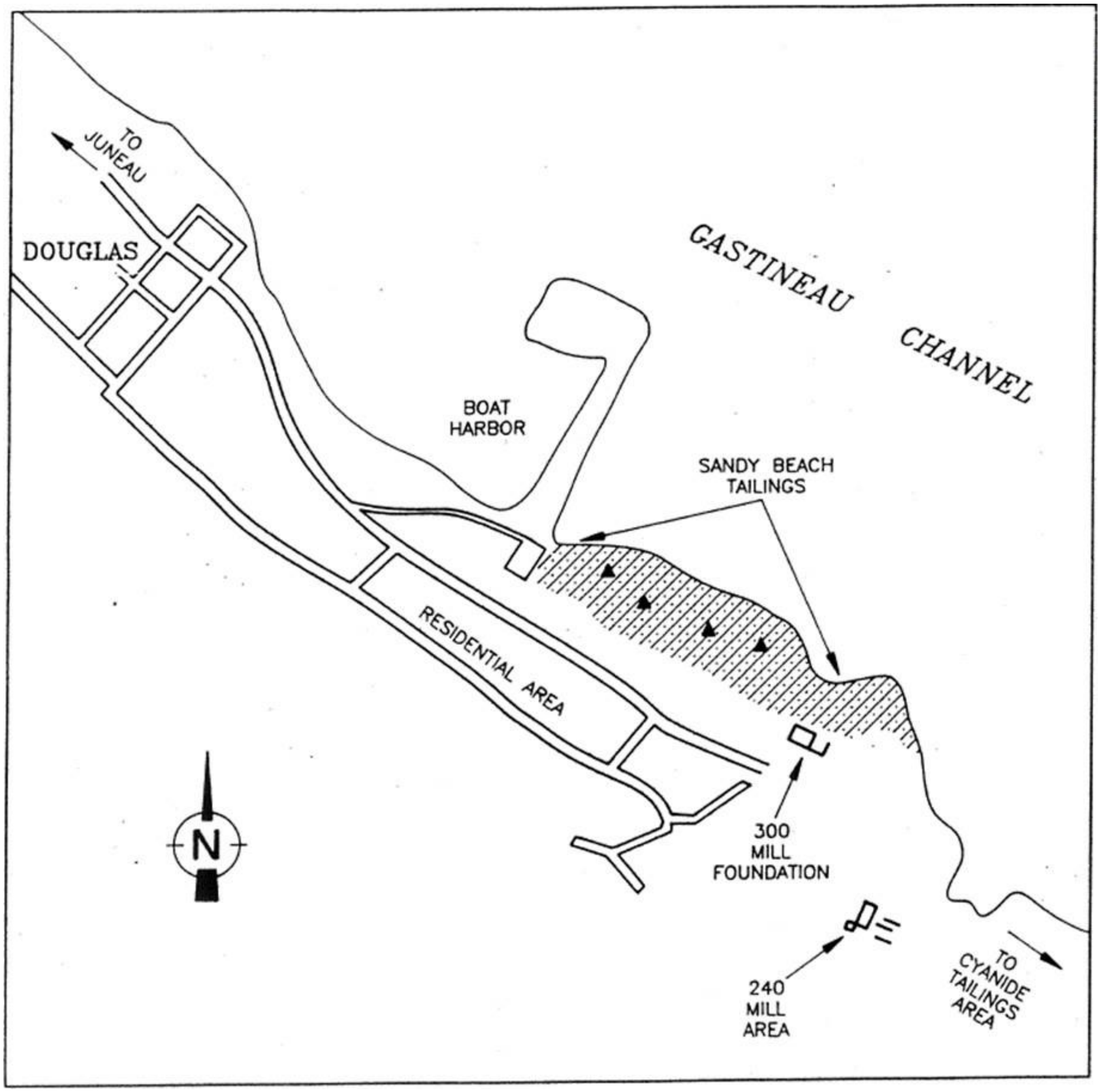
Sediment Screening. Maximum contaminant concentrations were compared to available background concentrations, ATSDR Comparison Values (CVs), and/or US EPA Regional Screening Levels (RSLs) for residential soil (Table C5 in Appendix C). Risk from exposure to lead in sediment and shellfish was estimated using the US EPA integrated exposure uptake biokinetic (IEUBK) model (see section D).

Figure C1. Location of background sediment samples on eastern shore of Lynn Canal, near Kensington Mine, Southeast Alaska



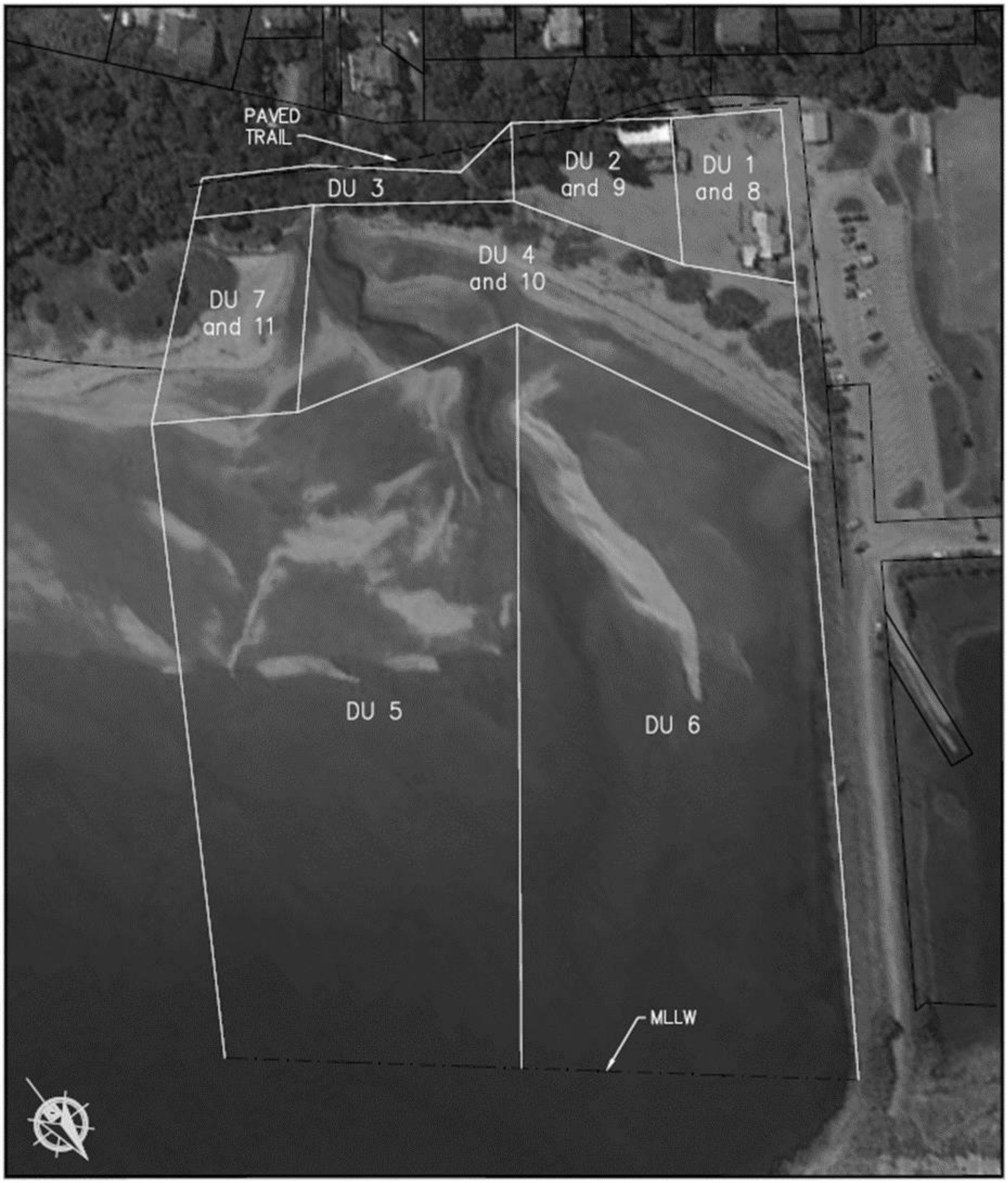
Source: Kensington mine area baseline contaminants study, Alaska. Juneau Field Office, Southeast Alaska Ecological Services, Juneau Alaska, U.S. Fish and Wildlife Service, Technical report SEES-TR-01-01.16 pp [Rudis 2001].

Figure C2. Location of sediment samples taken from Sandy Beach in 1991, Former Treadwell Mine Complex, Douglas, Alaska



Source: Site inspection report for Treadwell Mine, Juneau, Alaska. September 1991. Prepared for Alaska Department of Environmental Conservation by Ecology & Environment, Inc. [E&E 1991].

Figure C3. Location of planned soil or sediment sample areas from Savikko Park (Decision Unit 1, 2, 8, 9), Sandy Beach (4, 6, 10), Red Beach (5, 7, 11) and shoreline (3) at the Former Treadwell Mine Complex, Douglas, Alaska.



Source: Site assessment report, soil characterization at Savikko Park, Douglas, Alaska. Prepared for City and Borough of Juneau Engineering Department by Nortech Environmental Engineering and Industrial Hygiene. Where two DUs are listed, the smaller number is collected at a surface depth of 0-1.5 ft bgs, and the larger number is collected at a depth of 1.5–3 ft bgs (Note: Decision Units 3, 5 and 6 were not sampled due to logistical constraints) [Nortech 2013a].

Table C5. Screening of Site-related Sediment Contaminant Concentrations and Background Concentrations (mg/kg), Former Treadwell Mine Complex.

Contaminant	Number Sampled	Number Detected	Site Sediment Minimum mg/kg	Site Sediment Maximum mg/kg	Background (Juneau area) Sediment mg/kg (number)	Soil* Comparison Value (CV) mg/kg	Comparison Value type
Arsenic, Total	30	30	2.3	16.6	4.79 - 24.6 (7)	NA	NA (CVs based on inorganic arsenic)
Arsenic, inorganic	16	16	0.698	8.55	N/A	16	Chronic EMEG Child
Mercury, Total	29	29	0.1	1.83	0.011 - 0.17 J (3)	NA	NA (CVs based on methyl form of mercury)
Mercury, methyl	15	10	<0.00001 U	0.000499	N/A	5.2	Chronic EMEG Child
Lead	17	17	5.58	58.2	1.3 – 11 (7)	NA	NA (see discussion of IEUBK model)
Aluminum	1	1	1,660 J	1,660 J	18,800 J(1)	52,000	Chronic EMEG Child
Antimony	1	0	<12 U	<12 U	<14.6 U (1)	21	Chronic RMEG Child
Barium	9	9	80.1	249	N/A	10,000	Chronic EMEG Child
Beryllium	1	1	0.24	0.24	1.7 (1)	100	Chronic EMEG Child
Cadmium	9	9	0.0715 J	1.3 J	<0.11 U - 9.6 (7)	5.2	Chronic EMEG Child
Chromium (not speciated)	8	8	4.93	7.71	23.89 – 132 (7)	78,000(tri) 0.22 (hex)	Chronic RMEG Child (tri) ATSDR CREG (hex)
Copper	1	1	26.6 J	26.6 J	22.25 - 74.6 J (3)	1,000	Intermediate EMEG Child

Contaminant	Number Sampled	Number Detected	Site Sediment Minimum mg/kg	Site Sediment Maximum mg/kg	Background (Juneau area) Sediment mg/kg (number)	Soil* Comparison Value (CV) mg/kg	Comparison Value type
Iron	1	1	7,460 J	7,460 J	30,600 J (1)	55,000	EPA RSL Residential Soil
Manganese	1	1	398 J	398 J	416 (1)	1,800	EPA RSL Residential Soil
Nickel	1	1	8.5 J	8.5 J	16.96 - 74 J (3)	1,000	Chronic RMEG Child
Selenium	9	6	<0.150 U	0.422	<0.57 U (1)	260	Chronic EMEG Child
Silver	9	5	<0.0310 U	0.236	<0.9 U (1)	260	Chronic RMEG Child
Thallium	1	0	<0.47 U	<0.47 U	<0.57 U (1)	0.78	EPA RSL Residential Soil
Vanadium	1	1	14.6	14.6	56.8 (1)	520	Intermediate EMEG Child
Zinc	1	1	25.1	25.1	41.51 – 116 (7)	16,000	Chronic EMEG Child
Cyanide	2	2	0.037 J	0.06	0.068 - 0.086 (2)	33	Chronic RMEG Child

Sources: Sandy and Red Beaches: E&E 1991, DIA and ADEC 2011, Nortech 2013a, Ridolfi 2014, Ridolfi 2016; Juneau area: E&E 1991, Rudis 2001
Notes: Duplicate Samples were averaged; Maximum values were used to screen for chemicals of concern.
*ATSDR does not have sediment-specific CVs, so soil CVs were used for screening
Abbreviations
CalEPA – California Environmental Protection Agency
CREG – ATSDR's cancer remedial evaluation guide for chronic exposure to residential soil
EMEG – ATSDR's environmental media evaluation guide for noncancer health effects
EPA RSL – Environmental Protection Agency regional screening level, HQ = 1, November 2020
J – The analyte was positively identified; the associated number is an approximate concentration of the analyte.
mg/kg – milligram contaminant per kilogram sediment
n – number of samples
NA – not available
RMEG – remedial media evaluation guide based on EPAs reference dose
U – The analyte was analyzed for but not detected above the reported sample quantification limit.

Appendix D Evaluation of Health Risks posed by Metal Contamination in Shellfish

ATSDR estimated health risks from consumption of metals in shellfish from the former Treadwell Mine area, using two diet scenarios. We used protective assumptions regarding consumption rates and chemical forms of contaminants as inputs to ATSDR's public health assessment site tool (PHAST). PHAST calculates site-specific exposure doses for various exposure scenarios stipulated by the assessor. The program calculates a hazard quotient for each chemical and exposure scenario, specific for various age groups of consumers. The hazard quotient compares the calculated exposure dose to the most appropriate health guideline. The health guidelines incorporate protective assumptions, so if the exposure dose is less than the health guideline it can be inferred that any health risk from that exposure is minimal. In summary, several hazard quotients exceeded one for chronic or acute exposures, and these were further evaluated.

Four assumptions influenced the shellfish consumption exposure pathway:

Shellfish consumption rate based on traditional harvest rates. We researched seafood consumption rates specific to subsistence areas in southeast Alaska using Alaska Department of Fish and Game (ADFG) reports. Subsistence harvest reports were not available for the Juneau/Douglas area, which is designated by ADFG as a non-subsistence area. However, detailed harvest reports were available for the Southeast communities of Hoonah, Angoon [Sill 2017a] and Yakutat [Sill 2017b]. Each of these communities were mentioned by elders during interviews as areas where DIA members had dispersed to following the village burning in 1962, and/or areas where DIA members currently have family and friends. Harvest data included quantities collected for each species of shellfish (and many other types of subsistence foods), consumable pounds of meat per capita, and percent of population consuming each species. Consumption data for Hoonah were used as a proxy for shellfish consumption rates by DIA tribal members, as Hoonah had the greatest shellfish consumption rates of the three villages. Total usable pounds of shellfish for each species were divided by the number of people in the village that reported consumption of that species to calculate a daily rate of consumption among users of each resource. These consumption rates were used to calculate potential risks associated with a "traditional use" shellfish diet over the course of a lifetime, from 2 to 78 years of age.

Shellfish consumption rate based on "reasonable maximum exposure" (RME) use. ATSDR also evaluated potential risks at a consumption rate of one meal per month of each shellfish resource over the course of a lifetime, from 2 to 78 years of age. In this exposure scenario, children aged 2 to < 11 years old were assumed to eat 4-ounce meals, while older children and adults were assumed to eat 8-ounce meals. This consumption rate is consistent with the opportunistic, episodic resource use described by DIA members during interviews. Since there is a local homeless population [Tharp 2008] and the beach is easy to access, this is a plausible scenario for shellfish consumption in the homeless population as well.

Contribution of site shellfish to total diet. Calculations assumed that all shellfish eaten by DIA tribal members came from Sandy or Red Beach. During interviews, most elders reported that they did not currently eat any shellfish from Sandy or Red Beach. While some elders reported frequent shellfish harvest from Sandy and Red beaches in decades past, other elders indicated that the area had never been a frequent, primary source of subsistence shellfish. Currently, most DIA members obtain shellfish from the grocery store, or from friends or relatives that live in other Southeast villages that gather and share these resources. Observations of ATSDR personnel during site visits and site investigation reports indicate that shellfish were difficult to locate for sampling on Sandy and Red Beaches. The beaches do not have a lot of rocky outcroppings, which are the primary habitat for mussels. As mentioned above, homeless people may access shellfish at this site exclusively if they are living nearby.

Methyl mercury. There is no ATSDR comparison value for total mercury in shellfish. Methyl mercury was used to calculate the exposure point concentration when available. However, most of the ADEC samples only reported total mercury. Exposure point concentrations using total mercury were evaluated using the methyl mercury toxicity value as a surrogate. This was a protective approach, because methyl mercury is more toxic than other common mercury forms such as elemental (inorganic) mercury.

Inorganic arsenic. As explained in ATSDR's toxicological profile for arsenic [2007], most arsenic found in fish and shellfish is in an organic form which is less toxic than inorganic arsenic. ATSDR's comparison values are based on inorganic arsenic exposures. Measured inorganic arsenic was used to calculate the exposure point concentration when available. Inorganic arsenic was only measured in the biota samples collected by DIA/Ridofi – specifically, two dungeness crab samples, and one clam sample and its duplicate. In all other biota samples, which were collected by ADEC, only total arsenic in shellfish was analyzed, without speciating the specific arsenic forms. It was necessary to estimate the percentage of arsenic that was in the inorganic form in the ADEC shellfish samples, which introduced a source of uncertainty to the health effects evaluation for arsenic. (See next section)

Evaluation of Scientific Literature Related to Inorganic Arsenic in Shellfish

Several references were considered when selecting an assumed percentage of inorganic arsenic to apply for shellfish when only total arsenic concentrations were available. In a review, Lorenzana et al. [2009] concluded that the surveyed literature did not support the derivation of a nationwide default percentage of inorganic arsenic in shellfish from arsenic-contaminated areas. For shellfish surveyed in U.S. site assessments, the percent inorganic arsenic values for marine clams, cockles, and crabs were 2.6% or less, with the exception of two horse clam composites from Marrowstone Island in Puget Sound (12.5 and 13.7%) [Lorenzana et al. 2009]. The percentage of inorganic arsenic varies among shellfish species; it is influenced by ecological factors such as food sources, feeding strategies, habitat type (water column vs. sediment), and trophic level [Kato et al. 2020], and physicochemical factors such as salinity and pH [Maher et el. 2018]. Ultimately, ATSDR used the standard and protective assumption of 10% inorganic arsenic adopted by EPA [2003] and cited in the ATSDR toxicological profile, for mussels, cockles, crabs, and sea cucumbers. For clams, ATSDR assumed that 51% of total arsenic was in an inorganic form, based on the DIA clam sample in which that percentage was observed. Data were adjusted before inputting inorganic arsenic exposure point concentrations into PHAST.

Different species of clams have different life histories and habitat types, and these greatly impact both their degree of arsenic accumulation from the environment, and their relative percentages of inorganic arsenic [Rahman et al. 2012]. In an historical mining intertidal area in Nova Scotia with very high sediment arsenic levels, **softshell clams (*Mya arenaria*) accumulated much higher concentrations of arsenic** than blue mussels (*Mytilus edulis*) did [Doe et al. 2017]. In that study, the softshell clams accumulated arsenic levels up to 160-fold higher than the reference area, while blue mussels only accumulated up to 6-fold higher than the reference area. This was attributed to fact that blue mussels are not sediment infauna, so they do not regularly contact sediment. Mussels feed by filtering phytoplankton from the water column [Newell 1989]. In contrast, juvenile and adult softshell clams dwell within intertidal sediments [Newell 1986]. In addition to uptake through direct dermal contact with bed sediment, sediment-dwelling filter-feeding invertebrates like softshell clams can also uptake arsenic present in suspended particulate material (e.g., sediment, planktonic organisms, and detritus) and dissolved in the water column [Rahman et al. 2012]. In the Nova Scotia study, inorganic arsenic accounted for a much greater percent of total arsenic in softshell clams (mean = 17.0%; range = 6.5 – 45.4%,) than in blue mussels (mean = 6.7%, range = 1.2 – 17.8%) [Doe et al. 2017]. The high proportion of inorganic arsenic in softshell clams in arsenic contaminated areas may result from saturation of the metabolic pathways that convert inorganic arsenic into organic forms such as arsenobetaine [Koch et al. 2007]. **Thus, the ratio of inorganic arsenic to total arsenic in shellfish can vary depending on the degree of environmental contamination, and whether the detoxification pathway is saturated** [Whaley-Martin et al 2012]. In the St. Lawrence River, the inorganic arsenic percentage among 23 softshell clam homogenates ranged from 1.8 to 19%, with an average of 8.2% [Gagnon et al. 2004].

In this study of shellfish from Sandy and Red beaches, the percentage of one softshell clam composite and its duplicate was measured; it was 51% inorganic. This site-specific value was applied to all the ADEC clam samples, in which only total arsenic was measured. Field notes indicate that 6 of the 9 ADEC samples were "softshell clams", while the other 3 samples were "clams" (species not indicated). If those three samples were not softshell clams, it is probable that their inorganic arsenic content was over-estimated, as was their toxicity.

In a controlled laboratory study, Kerns et al. [2017] found that the inorganic arsenic taken up by softshell clams from contaminated sediments was highly concentrated in the siphon skin relative to the main body, by several orders of magnitude. **Human consumers of softshell clams can greatly reduce their exposure to arsenic by removing the siphon skin prior to consumption** [Kerns et al. 2017].

Evaluation of Noncancer Health Hazards associated with Shellfish Consumption

PHAST calculated a hazard quotient (HQ) for each chemical and exposure scenario, using the formula

HQ = calculated exposure dose/health guideline

If an HQ is above one an adverse health effect may be possible, so the health assessor performs additional evaluation for those scenarios. Hazard quotients at or above 1.0 were calculated for the consumption scenarios shown in Tables D1. Please refer to Appendix E for all hazard quotient results, for every shellfish species/chemical/exposure scenario combination.

Table D1. Summary of hazard quotients by chemical and exposure scenario for each shellfish species at or above 1.0; Former Treadwell Mine Complex, Douglas Alaska

Shellfish Species	Chemical	Exposure Scenario*	Health Effect Exposure Type	Age (years) of Exposure Group	Dose (µg/kg/d)	Hazard Quotient	Table E Ref
Clams	Inorganic arsenic	Traditional (Hoonah)	Chronic	2 to < 6	1.1	3.7	E1a
Clams	Inorganic arsenic	Traditional (Hoonah)	Chronic	6 to < 11	0.61	2.0	E1a
Clams	Inorganic arsenic	Traditional (Hoonah)	Chronic	11 to < 16	0.68	2.3	E1a
Clams	Inorganic arsenic	Traditional (Hoonah)	Chronic	16 to < 21	0.54	1.8	E1a
Clams	Inorganic arsenic	Traditional (Hoonah)	Chronic	Adult (21+)	0.48	1.6	E1a
Clams	Inorganic arsenic	Traditional (Hoonah)	Acute	2 to < 6	8.0	1.6	E1b
Clams	Inorganic arsenic	One meal a month	Acute	2 to < 6	8.0	1.6	E6b
Clams	Cadmium	Traditional (Hoonah)	Chronic	2 to < 6	0.10	1.0	E1c
Clams	Copper	Traditional (Hoonah)	Acute	2 to < 6	24	1.2	E1f
Clams	Copper	One meal a month	Acute	2 to < 6	24	1.2	E6f
Sea Cucumber	Copper	Traditional (Hoonah)	Acute	2 to < 6	91	4.6	E5f
Sea Cucumber	Copper	Traditional (Hoonah)	Acute	6 to < 11	50	2.5	E5f
Sea Cucumber	Copper	Traditional (Hoonah)	Acute	11 to < 16	56	2.8	E5f
Sea Cucumber	Copper	Traditional (Hoonah)	Acute	16 to < 21	44	2.2	E5f
Sea Cucumber	Copper	Traditional (Hoonah)	Acute	Adult (21+)	40	2.0	E5f
Sea Cucumber	Copper	One meal a month	Acute	2 to < 6	91	4.6	E10f
Sea Cucumber	Copper	One meal a month	Acute	6 to < 11	50	2.5	E10f
Sea Cucumber	Copper	One meal a month	Acute	11 to < 16	56	2.8	E10f

Sea Cucumber	Copper	One meal a month	Acute	16 to < 21	44	2.2	E10f
Sea Cucumber	Copper	One meal a month	Acute	Adult (21+)	40	2.0	E10f

*Assumed meal size is 4 ounces for children between the ages of 2 to <11 years old, and 8 ounces for adults and children 11 years of age or older

ATSDR has developed comparison values called minimal risk levels, which are estimated contaminant exposure doses that are not expected to result in adverse noncarcinogenic health effects, based on evaluation of published toxicological studies. MRLs are developed based on exposure duration, that apply to acute (14 days or less), intermediate (15 – 365 days) and chronic (365 days or more) exposures. Not all chemicals have MRLs for each exposure duration. For example, copper's toxicity is quick-acting so there are acute and intermediate MRLs. No separate chronic MRL for copper has been developed by ATSDR, because there are insufficient studies of chronic health effects from exposure to this essential element. In Table D1, the type of health effect exceeded based on exposure duration is noted under the column "Health Effect Exposure Type".

No MRLs were exceeded for cockles, dungeness crabs, or mussels from the former Treadwell Mine site, under any evaluated exposure scenario. No MRLs were exceeded for methyl mercury, selenium, or cyanide, for any shellfish species or exposure scenario evaluated. The toxicity and risks associated with these chemicals in site shellfish are minimal and are not further evaluated.

Since inorganic arsenic, cadmium and copper were the only chemicals with some hazard quotients at or above one, ATSDR conducted a more in-depth evaluation of cadmium, copper, and arsenic exposures and associated hazards.

Cadmium

The hazard quotient for chronic exposure to cadmium was 1.0 for a sole exposure scenario: consumption of clams from the former Treadwell mine site by children two to six years old, at a traditional (Hoonah) diet rate of 51 4-ounce meals per year (Table E1c). This is a highly improbable current exposure scenario, although it may have been more likely in the distant past.

The chronic oral cadmium MRL is 0.0001 mg/kg/day, which is equal to the exposure dose for the 2- to 6-year-old child. The chronic MRL is based on a point-of-departure dose of 0.0003 mg/kg/day, and it incorporates a three-fold safety factor to account for variability among humans. The toxicity endpoint was the 95% lower confidence limit on a 10% excess risk of low molecular weight proteinuria, a biomarker of kidney function, by the age of 55 years after a lifetime of exposure.

Given that a consumption rate of 51 4-ounce meals per year of clams by young children is unlikely, and that the scenario dose is three-fold below the minimal risk level dose for proteinuria over a lifetime of exposure, the intake of cadmium from clams at the site does not pose a human health hazard.

Copper

Exposure to dietary copper at environmentally relevant doses is not generally of chronic health concern, but there are intermediate and acute MRLs for ingestion of copper. Copper was present in sea cucumbers at the site at a maximum level (14 ppm) that produced a hazard quotient of 1.3 for children aged 2 to 6 years of age, under either dietary scenario. Hazard quotients for acute copper exposures from sea cucumber consumption ranged from 4.0 (for adults) to 9.1 (for small children). Risk estimates for sea cucumber are uncertain because they are based on only two samples.

Hazard quotients for acute copper exposures from clam consumption ranged from 1.0 (for adults) to 2.4 (for young children), under either diet scenario.

The health effect upon which both the intermediate and acute copper MRLs are based is gastrointestinal symptoms such as nausea, abdominal pain, diarrhea and/or vomiting. The key studies upon which the MRLs are based were both for human exposures from copper sulfate in drinking water.

The study upon which the acute copper MRL is based notes, "If we extrapolate our findings to the usual form of copper exposure (i.e., copper-contaminated water consumed with food), we should consider that food would bind the copper ions, preventing gastrointestinal symptoms. Thus, consumption of the plain water and not copper with food would have a higher risk of triggering acute gastrointestinal manifestations" [Pizarro 1999].

ATSDR's MRL is based on copper sulfate in drinking water [ATSDR 2004], so its direct application to copper exposures in food may overestimate actual risk. Copper absorption in food ranges from 15-97%, depending on copper content and composition of the diet [Stern et al. 2007]. The absorption of copper from food is a complex process that is mediated by several factors [Hund-Rinke and Kordel 2003]. Some factors are intrinsic to the food item (such as the carbohydrate, fiber, and protein content), while other factors such as nutritional status [Turnlund. et al. 1989] and genetics are intrinsic to the consumer eating the food [Peijnenburg and Jager 2003]. The variability in copper bioavailability from foods adds uncertainty regarding the toxicity of copper consumed within food.

The Dose-Response relationship of both excess and deficiency of copper

Copper is an essential element in humans, and it is needed for homeostatic maintenance [Stern et al. 2007]. Tight coordination of copper uptake, distribution, and efflux in cells and the whole organism is required to maintain a constant internal environment. The fraction of copper absorbed from food decreases with increasing level of dietary copper. Changes in endogenous biliary secretion may be the primary mechanism for regulation of total body copper, rather than direct changes in gastrointestinal absorption [Turnlund et al. 1989; Stern et al. 2007].

Clinically evident copper deficiency is rare in humans; it occurs most commonly in low-birth-weight neonates, and in infants and children with inadequate nutrition. The effects of copper deficiency include anemia, neutropenia, and bone-marrow abnormalities that resolve when the infants are given copper supplementation [Cordano 1978)]. Copper is also essential for bone formation, cardiac function, lipid metabolism, immune function, neurological development, and maturation of blood cells [Danks 1988]. Typical diets in the United States meet or exceed the copper Recommended Dietary Allowance. Inadequate copper status is most common among people with excessive use of zinc supplements, and people with celiac disease or Menkes disease [National Institutes of Health 2021].

Since copper is an essential element, dose-response relationships should be developed for both copper excess and deficiency. The dose-response curve for copper is a U-shaped curve, where both deficient and excess copper have adverse effects. It is even possible that there is a range of copper values at which deficiency and excess might occur in different individuals at the same copper level. In that situation, one would like to estimate the copper dose at which the likelihood of adverse effects from either deficiency or excess is minimized in the population [Stern et al. 2007]. Several researchers have examined the dose-response relationship for both deficiency and excess of copper [Aggett 1999; Stern et al. 2007]. When a one-sided evaluation occurs based solely on toxicity, with uncertainty factors weighted toward conservatism, the derived “safe level” benchmark may actually lie within the element’s “sweet spot” of “adequate” intake at the bottom of the U-shaped curve. Take, for example, ATSDR’s new provisional acute oral MRL of 20 µg/kg/day for copper, which is based on a 50 µg/kg/day $BMDL_{10}$ [ATSDR 2021]. Aggett’s postulated spectrum of copper metabolism indicates that the range from 9 to 100 µg/kg/day copper bounds the “adequate” range [Aggett 1999] (Table D2). Table D1 (above) indicates that all of the calculated PHA doses with HQs above 1.0 for the Treadwell Mines PHA fall within the “adequate” range of copper (the “elevated” PHA copper doses ranged from 10 to 91 µg/kg body weight/day.)

The Food and Nutrition Board at the U.S. National Academies of Sciences, Engineering, and Medicine has established dietary recommendations for copper intake, including recommended dietary allowances and tolerable upper intake levels [Institute of Medicine 2001] (Table D3). Their age brackets do not correspond precisely to the age-specific dose-response brackets provided by PHAST; regardless they are shown in comparison to the copper doses calculated in PHAST for site-specific copper exposures from sea cucumbers and clams at Treadwell Mines in Table D3. Note that since the primary risks of concern are for acute exposure, the individual meal size is responsible for the calculated risk; hence either dietary scenario produces the same daily dose and risk result.

Table D2. The Copper Metabolism Spectrum (from Aggett, 1999)

Dose range	Approximate intake (µg/kg body wt/day)	Health outcomes
Toxic	-	Death
	-	Gross dysfunction and disturbance of other nutrients; hepatic "detoxification" and homeostasis overwhelmed
	>5,000	Gastrointestinal metallothionein induced (possible differing effects of acute and chronic exposure)
Adequate	100	Plateau of absorption maintained; homeostatic mechanisms regulate absorption of copper
	34	Hepatic uptake, sequestration and excretion effect homeostasis; glutathione-dependent uptake of copper; binding to metallothionein; and lysosomal excretion of copper
	11	Biliary excretion and gastrointestinal uptake normal
	9	Hepatic deposit(s) reduced; conservation of endogenous copper; gastrointestinal absorption increased
Deficient	8.5	Negative copper balance
	5.2	Functional defects, such as lysyl oxidase and superoxide dismutase activities reduced; impaired substrate metabolism
	2	Peripheral pools disrupted; gross dysfunction and disturbance of metabolism of other nutrients; death

Source: Aggett 1999

Table D3. Recommended Dietary Allowances and Tolerable Upper Intake Levels for Copper, with comparison to acute daily copper doses from sea cucumber or clam exposures from the Former Treadwell Mines complex. All doses shown are in micrograms per day.

Age (Institute of Medicine brackets)*	Cu RDA (µg/day)	Cu TUL (µg/day)	Site Sea Cucumber Daily Cu Dose (µg/day)	Site Clam Daily Cu Dose (µg/day)
1-3 yrs**	340	1,000	1,583 (age 2 to < 6 yrs.)	417 (age 2 to <6)
4-8 yrs.	440	3,000	1,590 (age 6 to < 11 yrs.)	413 (age 6 to <11 yrs.)
9-13 yrs.	700	5,000	3,181 (age 11 to <16 yrs.)	852 (age 11 to <16 yrs.)
14-18 yrs.	890	8,000	3,181 (age 11 to <16 yrs.)	852 (age 11 to <16 yrs.)
19+ yrs.	900	10,000	3,150 (age 16 to 21 yrs.)	859 (age 16 to 21 yrs.)
Pregnancy	1,000	See age group		
Lactation	1,300	See age group		

Abbreviations: RDA – Recommended Dietary Allowance, TUL – Tolerable Upper Intake Levels; µg – microgram
Notes:
* Where age brackets differ between the Institute of Medicine and ATSDR, comparisons are made to the younger Institute of Medicine bracket for a move conservative comparison. Daily doses were derived using ATSDR's defaults for each age.

group, and a meal size of 4 ounces for children aged 2 to < 11 years or 8 ounces for older children and adults.
**Highlighted cells indicate exceedance of RDA and TUL that may result in adverse effect and warrant additional evaluation.

Bottom Line: Acute copper exposures from clam consumption do not exceed the tolerable daily intake for any age group, and they are not of health concern. It is uncertain whether consumption of sea cucumbers, which contain rather high concentrations of copper, may cause gastrointestinal upset following a meal. For most age groups, a typical copper dose from a sea cucumber meal falls between copper's recommended dietary allowance and the tolerable upper intake level (Table D3). However, young children may be particularly vulnerable to potential gastrointestinal upset following a sea cucumber meal. A child younger than age 6 years would have a copper intake above the tolerable daily intake following a 4-ounce sea cucumber meal. Parents may choose to feed their children smaller sea cucumber meals, or to refrain from feeding their small children sea cucumbers, to avoid stomach aches, diarrhea, vomiting or other gastrointestinal symptoms.

These conclusions are uncertain for several reasons. Only two sea cucumber samples were collected, and it is uncertain whether the copper concentrations in those two samples are representative of the broader sea cucumber population in the area. The degree to which copper from sea cucumbers is bioavailable to a human consumer is also uncertain.

Arsenic

Hazard quotients for non-carcinogenic effects of inorganic arsenic were only above 1.0 for some clam exposure scenarios; hazard quotients were below 1.0 for all other sampled shellfish. There are two main reasons why inorganic arsenic was a greater problem in clams than in other types of sampled shellfish. First, the traditional diet (Hoonah) consumption rate of clams was high, at 51 meals per year. Only cockles rivalled that consumption rate, at 53 meals per year for the traditional diet scenario. Second, although the sample size was very limited, the available data showed that the percentage of total arsenic present in the more toxic inorganic form (51%) was much higher in softshell clams from the site than is generally seen in other types of seafood (often <1%).

The hazard quotient for acute exposure to inorganic arsenic in clams was only above one (1.6) for the 2- to < 6-year-old age group, under either diet scenario. The hazard quotient for chronic exposure to inorganic arsenic in clams exceeded one for all age groups when the traditional diet scenario was applied, ranging from 1.6 (in adults) to 3.7 (in young children).

The MRL for acute inorganic arsenic exposure is based on data from an episode of arsenic contamination of soy sauce in Japan in the 1950s [Mizuta 1956]. For derivation of the acute oral MRL of 0.005 mg As/kg/day, facial edema and gastrointestinal symptoms such as nausea, vomiting and diarrhea were the critical effects [ATSDR 2007]. The MRL for acute inorganic arsenic exposure is based on a LOAEL rather than a NOAEL; a ten-fold safety factor was incorporated into the MRL to reflect that source of uncertainty. The inorganic arsenic dose for children ages 2 to <6 years exposed acutely to site clams is 0.008 mg/kg/day (Table E1b), which is less than two-fold above the acute MRL of 0.005

mg/kg/day, and more than six times lower than the LOAEL of 0.05 mg/kg/day at which health effects were observed in the study from Japan. Considering the safety factor built into the MRL, the possibility of over-estimation of the percent arsenic present in the inorganic form, and the unlikelihood that arsenic within the clams was completely bioavailable, it is unlikely that arsenic in clams from the site poses an acute health hazard to young children.

The MRL for chronic inorganic arsenic exposure is based on a large group of poor farmers exposed to high levels of arsenic in well water in Taiwan. The chronic health effect on which the MRL was based is characteristic dermal lesions (hyperkeratosis and hyperpigmentation). The MRL of 0.0003 mg As/kg/day is based on a NOAEL of 0.0008 mg As/kg/day observed in a large control population and incorporates a three-fold safety factor for individual variation among people. The exposure doses calculated for the various age groups that consume clams under a traditional diet scenario ranged from 0.00048 mg As/kg/day (in adults) to 0.0011 mg As/kg/day (in young children). The NOAEL for chronic inorganic arsenic exposure (0.0008 mg As/kg/day) was only exceeded in the 2- to < 6-year-old age group, by less than a factor of two. The chronic inorganic arsenic dose children ages 2 - <6 years (0.0011 mg As/kg/day) is more than twelve-fold lower than the LOAEL of 0.014 mg As/kg/day, at which dermal health effects were observed in the key study.

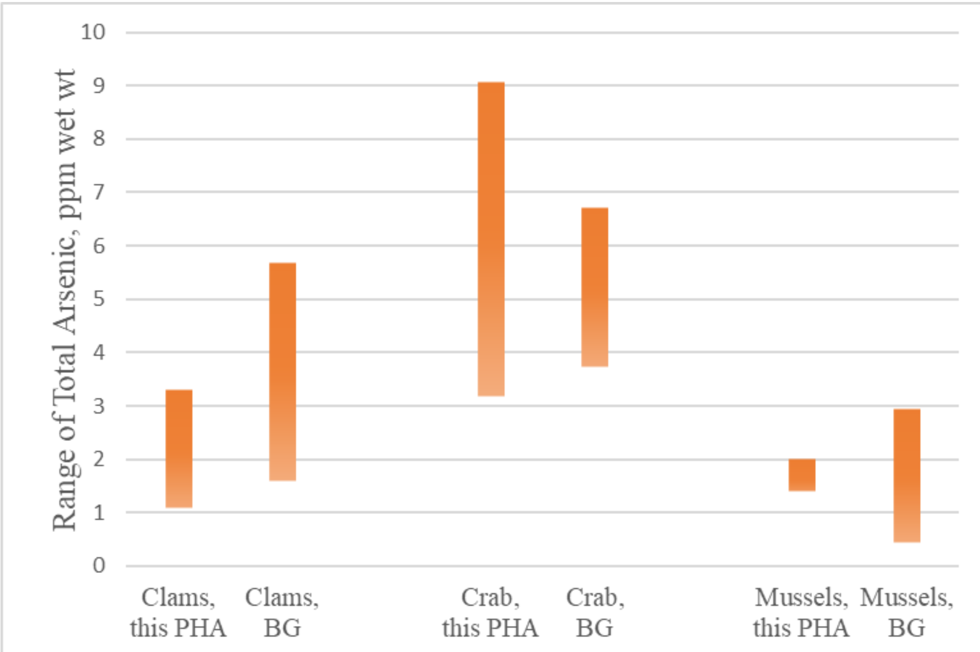
Arsenic in clams from the site do not pose a chronic health hazard because the percent of inorganic arsenic may have been overestimated, and it is unlikely that the arsenic within the clams was completely bioavailable or that anyone eats 51 meals per year of clams from the site. People who wish to reduce their arsenic exposure while still enjoying shellfish can choose to eat clam species other than softshell clams, or to remove the siphon before consuming softshell clams since arsenic is concentrated in the siphon [Kerns 2017].

Comparison of metals concentrations in site-related shellfish to those collected at background sites.

To put the health risks posed by metals in site shellfish in perspective, it is helpful to compare the metals levels from site shellfish with those from shellfish in nearby areas that aren't impacted by the site. The metals found in site shellfish are also naturally found in the earth's crust, and there is a natural "background" level of the metals in the environment, including soil, sediments, water, plants, and animals.

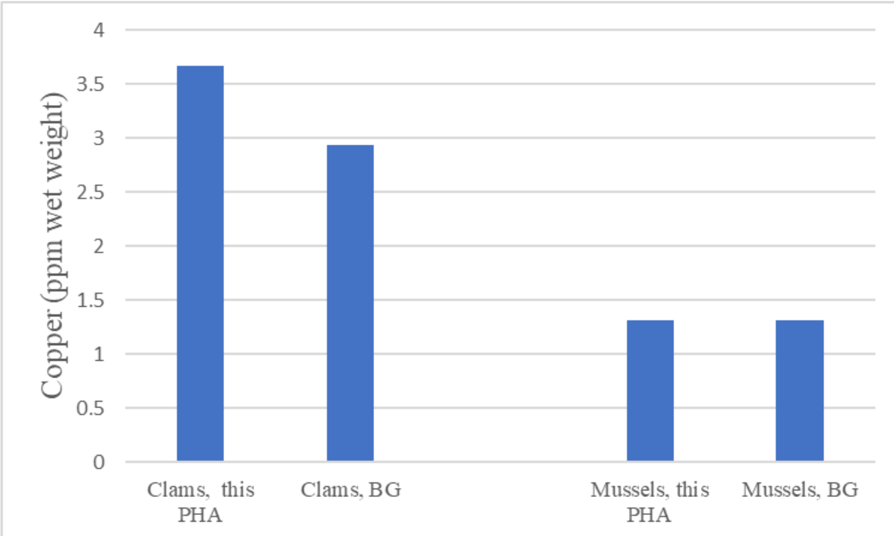
ATSDR identified two appropriate background data sets for shellfish from Southeast Alaska for comparative use. Background mussel samples were collected from Lynn Canal (north of the Juneau area) prior to establishing the Kensington Mine [Rudis 2001]. Background crab and clam samples were taken from Browns Bay as reported in the Salt Chuck Mine Superfund Site Remedial Investigation [EPA 2018]. ATSDR focused on total arsenic in shellfish for the background evaluation instead of inorganic arsenic because the inorganic arsenic data are too sparse. A summary of the background shellfish data is presented in Table C3 of Appendix C.

Figure D1. Comparison of Total Arsenic Concentration Range in Shellfish from the Former Treadwell Mines site ("this PHA") to Shellfish from Two Background ("BG") Areas in Southeast Alaska



It was not possible to perform rigorous statistics on the two data sets because the number of samples was too small, and there were some methodological differences between the studies. The range of total arsenic concentrations in clams, dungeness crabs, and mussels from Sandy and Red Beaches were similar to arsenic levels found in the background studies (Figure D1).

Figure D2. Comparison of Copper in Shellfish (95 UCL of the mean) from the Former Treadwell Mines site ("this PHA") to Shellfish from Two Background ("BG") Areas in Southeast Alaska



Average copper levels in mussels from the former Treadwell Mine Complex were nearly identical to those found in mussels from the background area. Average copper levels in clams from the site were slightly higher than copper levels from the background area (Figure D2).

Total Arsenic and Copper in Site-Related Shellfish Compared to Seafood in the FDA Market Basket Survey

The U.S. Food and Drug Administration (FDA) conducts a total diet study (also called "market basket" surveys) to monitor levels of about 800 contaminants and nutrients in the average U.S. diet. To conduct the study, the FDA buys, prepares, and analyzes about 280 kinds of foods and beverages from representative areas of the country, four times a year.

ATSDR compared the levels of total arsenic (Table D4) and copper (Table D5) found in site-related shellfish with the levels found in market basket foods that contained seafood. The most recent market basket report contains metals results for 32 samples of each food type, collected from 2006 to 2013 [FDA 2017].

The foods from the FDA market basket survey are not the same as the unprepared shellfish samples analyzed from the former Treadwell Mine site, so the arsenic and copper levels cannot be directly compared. Tables D2 and D3 illustrate that grocery store foods also contain arsenic and copper; they should not be assumed to be "safer" or "less contaminated" than locally harvested foods. All foods contain both chemicals and nutrients, and a variety of different foods should be consumed and enjoyed as part of a healthy, balanced diet.

Table D4. Total Arsenic Concentrations (ppm wet weight) in clams from the Former Treadwell Mine site, clams from a background location in Southeast Alaska, and FDA Market Basket samples.

	Min	Arithmetic Average	Max
Clams, this PHA	1.1	1.745	3.3
Background, SE AK clams*	1.6	3.13	5.67
FDA Fish Sticks**	0.055	0.504	0.78
FDA Shrimp, boiled**	<0.02	0.315	1.4
FDA Clam Chowder**	<0.02	0.127	0.198
FDA Salmon, baked fillet**	<0.02	0.293	0.436
FDA Tuna, canned in water**	0.349	0.999	1.9

Sources
* Salt Chuck Mine remedial investigation (n=21), EPA 2018
** FDA 2017 (n=32 for each food type)
Abbreviations: EPA – Environmental Protection Agency, FDA – Food and Drug Administration, PHA – public health assessment, SE AK – Southeast Alaska

Table D5. Copper concentrations (ppm wet weight) in clams and mussels from the Former Treadwell Mine site, two background locations in Southeast Alaska and FDA Market Basket samples.

Shellfish Species	Copper Concentration Minimum (ppm wet weight)	Copper Concentration Arithmetic Average (ppm wet weight)	Copper Concentration Maximum (ppm wet weight)	Copper Concentration 95 UCL of the mean (ppm wet weight
Clams, this PHA	0.64	2.86	4.1	3.674
Background, SE AK clams*	1.28	2.52	5.65	2.932
Mussels, this PHA	1.10	1.26	1.4	1.32
Background, SE AK mussels**	0.80	1.20	1.48	1.31
FDA Fish Sticks#	<0.3	0.7	1.2	NA
FDA Shrimp, boiled#	0.8	1.3	3.3	NA
FDA Clam Chowder#	<0.3	0.05	0.4	NA
FDA Salmon, baked fillet#	0.4	0.5	0.8	NA
FDA Tuna, canned in water#	<0.3	0.3	0.6	NA

Sources:
* Background clams are from Brown's Bay; Salt Chuck Mine Remedial investigation (n=21), EPA 2018
** Background mussels are from Lynn Canal; n=13 [Rudis 2001]
# FDA 2017 (n=32 for each food type)
Abbreviations: EPA – Environmental Protection Agency, FDA – Food and Drug Administration, PHA – public health assessment, SE AK – Southeast Alaska, UCL – 95th upper confidence limit of the mean, NA – Not Available.

Evaluation of Cancer Risks associated with inorganic arsenic in shellfish.

Inorganic arsenic was the only known carcinogen evaluated in this report. ATSDR estimated a theoretical excess lifetime cancer risk for inorganic arsenic exposure from the both the traditional (Hoonah) and one-meal-a-month diets, using the same exposure scenarios described previously for noncancer health endpoints. The following equation was used for the calculation:

Theoretical Cancer Risk = Dose x CSF

Where:

Theoretical cancer risk = Expression of the cancer risk (unitless)

Dose = site-specific arsenic dose (mg chemical/kg body weight/day)

CSF = cancer slope factor established by EPA (mg chemical/kg body weight/day)$^{-1}$

This calculation estimates a theoretical excess cancer risk expressed as the proportion of a population that may be affected by a carcinogen during a lifetime of exposure. For example, an estimated cancer risk of 1×10^{-6} predicts that one additional cancer case may occur in a population of 1 million people exposed at the same level. EPA uses protective models to derive a cancer slope factor for each carcinogen, which is used to calculate a theoretical estimate of risk.

The U.S. EPA uses a range of 1 in 10,000 (1×10^{-4}) to 1 in 1,000,000 (1×10^{-6}) to make risk management decisions at Superfund sites. This is a theoretical estimate of cancer risk used by ATSDR as a tool for deciding whether public health actions may be needed to protect health. These theoretical cancer risk estimates apply to people with the same exposure assumptions (e.g., arsenic concentration in food, food ingestion rate, specified duration), and cannot be viewed as a precise cancer risk for an individual or a community where these assumptions vary throughout the population.

Because of conservative models used to derive CSFs, using this approach provides a theoretical estimate of risk; the true or actual risk is unknown and could be as low as zero [EPA 2005].

According to the American Cancer Society, the overall probability that residents of the United States will develop some type of cancer during their lifetime is 40.9% for men and 39.1% for women (almost 1 in 2) [ACS 2023]. One excess cancer case per million people in a population would be very difficult to detect atop the high background cancer incidence.

Table D4 shows that clam consumption poses the greatest risk of increased excess lifetime cancer incidence among the shellfish species analyzed. Excess cancer incidence is predicted to be above EPA's risk range of 1 in 10,000 (1×10^{-4}) under both the traditional (Hoonah) diet and one-meal-a-month scenarios. The excess cancer risk from consumption of inorganic arsenic in clams poses a moderate concern, but it is not all site related. Ingestion of inorganic arsenic in clams from the background area at the traditional (Hoonah) consumption rate would also pose a cancer risk above EPA's risk range.

Stone and Hope [2009] make a strong case against issuing fish advisories based on theoretical cancer risks from contaminants. The health benefits of seafood consumption are well-known, while cancer risk assessment methodology may overestimate cancer risk, often by orders of magnitude. Seafood advisories may potentially diminish opportunities for the recognized health and cultural benefits associated with a seafood-rich diet. In this case, ATSDR does not recommend reduced consumption of clams because arsenic levels from clams at the site are similar to those in clams from background sites and seafood from the grocery store. Arsenic intake can be reduced by avoiding softshell clam consumption or by removing the siphon from softshell clams prior to consumption.

Table D6. Excess lifetime cancer risk (ELCR) for exposure to inorganic arsenic in shellfish from the Former Treadwell Mine site or a background area from Southeast Alaska, ranked from highest to lowest risk. Highlighted scenarios exceed the U.S. EPA risk management range for management of Superfund sites.

Shellfish Species	Source	Exposure Scenario	Excess Lifetime Cancer Risk	Table E Reference
Clams†	Treadwell Mines	Traditional (Hoonah)	7.9E-04	E1a
Clams†	Background	Traditional (Hoonah)	2.2E-04	E11a
Clams†	Treadwell Mines	One Meal a Month	1.9E-04	E6a
Cockles†	Treadwell Mines	Traditional (Hoonah)	1.1E-04	E2a
Clams*	Background	One Meal a Month	5.2E-05	E11b
Sea Cucumber	Treadwell Mines	One Meal a Month	3.5E-05	E10a
Mussels	Treadwell Mines	One Meal a Month	2.7E-05	E9a
Cockles	Treadwell Mines	One Meal a Month	2.4E-05	E7a
Dungeness Crab	Treadwell Mines	Traditional (Hoonah)	1.1E-05	E3a
Dungeness Crab	Treadwell Mines	One Meal a Month	6.1E-06	E8a
Mussels	Treadwell Mines	Traditional (Hoonah)	4.5E-06	E4a
Sea Cucumber	Treadwell Mines	Traditional (Hoonah)	3.0E-06	E5a

* Source: Background clams are from Brown's Bay; Salt Chuck Mine remedial investigation (n=21), EPA 2018.

†Highlighted rows indicate scenarios that exceed the U.S. EPA risk management range for management of Superfund sites

Evaluation of Lead in Sediment (Beach Sand) and Food

The health risks posed by lead at a site are evaluated differently than other chemicals. Health-based comparison values for soil or food have not been developed for lead, because researchers have determined there is no "safe" blood lead level. The most meaningful predictor of potential health implications from lead exposure is the concentration of lead in the blood of an exposed individual.

Health assessors often use a modeling approach to predict a theoretical increase in blood lead levels that might occur from environmental exposures. ATSDR used EPA's integrated exposure uptake biokinetic model (IEUBK) [EPA 2021] to estimate blood lead levels of children visiting the site daily and/or eating shellfish from the site at a consumption rate of once a week over 90 days or more, which is required to achieve a steady state of blood lead concentrations in the model.

Sediment. The average lead concentration from sediment (beach sand) at the site is 11.4 ppm and ranged from 5.58 to 58.2 ppm. U.S. Geological Survey estimated the arithmetic mean for soil in Alaska as 14 ppm (n=437) with samples ranging from less than 4 ppm (detection limit) to 310 ppm [Gough et al. 1988]. As the average lead concentration is site sediment (beach sand) is below the average soil lead concentration in the state, there is likely not a site-related source of lead.

ATSDR used EPA's integrated exposure uptake biokinetic model (IEUBK) and incorporated the average lead concentration from sediment beach sand (11.4 ppm) as the concentration to which children are exposed to in the model. The model predicts a geometric mean for child's blood lead of 1.154 µg/dL and less than 0.091% probability that a child playing in this location every day for 90 days or more would have a blood lead higher than 5 ug/dL[3] (Figure D3). This exposure scenario overestimates a child's exposure because it assumes daily visits to the beach, and still does not appear to appreciably increase the blood lead of a child visiting the site.

Food. Consumption rates of crab, mussel, or sea cucumber were not frequent enough (see Table 2 in main text) to assess steady state blood lead levels in the model, which requires a minimum frequency of one meal a week for at least three months. The only shellfish with sufficient consumption frequency to

[3] In October 2021, CDC updated the blood lead reference value (BLRV) from 5 µg/dL to 3.5 µg/dL [CDC 2021]. However, lead models are not currently validated for levels below 5 µg/dL. Therefore, ATSDR uses 5 µg/dL in the models in our health evaluations until the updated BLRV of 3.5 µg/dL can be verified by EPA in their models.
CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard. States independently determine action thresholds based on state laws, regulations, and resource availability. CDC encourages healthcare providers and public health professionals to follow the recommended follow-up actions based on confirmed blood lead levels (https://www.cdc.gov/nceh/lead/advisory/acclpp/actions-blls.htm).

use the IEUBK model were clams and cockles under the traditional diet scenario (Hoonah consumption rate).

To estimate site-specific lead exposures to food, ATSDR used the diet and soil/dust parameters in IEUBK. We used the site-specific soil lead concentration of 11.4 ppm, as explained above. The diet parameter was changed by 'alternate dietary values' to include shellfish in the meat intake of children. ATSDR altered the 'fish for fishing' values using site-specific concentrations (µg lead/g of meat) and percent that clams and/or cockles contribute to the meat estimated in a child's diet.

To determine the amount of clams and or cockles a tribal child would eat, we derived the number of meals per year from the traditional (Hoonah) diet (Table 3 in the text) (Sill 2017a)]. The number of clam and cockle meals per year were 50 and 53 meals, respectively. Either of these meals represent approximately 1 meal per week. We assumed that a child eats one meat meal per day, so on the days the child eats shellfish they are not consuming any other type of meat. At a consumption frequency of 1 day per week, the percentage of meat as clams or cockles is 1/7 or 14%. Eating both one meal of clams and one meal of cockles per week would constitute 2/7 or 28% of total weekly meat intake (Table D7).

The default values for the dietary lead intake variable in IEUBK represent age-specific average estimates for lead intake from food for children (yearly from birth to 7 years of age) [EPA 2020 a,b]. For default values, EPA multiplied the age-specific ingestion rates from two cycles of NHANES What We Eat in America (WWEIA) survey data (2003-04 & 2005-06) [CDC 2010 a,b] by the mean lead concentration in food categories from ten years of FDA's Total Diet Survey data (1995-2005) [FDA 2010] to get default daily lead intakes (µg Pb/day). For the meat category, which shellfish are a part of, the IEUBK v.2 model uses a default mean concentration of 4.45 µg Pb/g meat [EPA 2021].

Table D7 and Figures D4, D5 and D6 show the assumptions and output from using site-specific diet data by using alternate dietary values as 'fish' in the model. **Probability of predicted blood lead levels above 5 µg/dL[4] from consuming these shellfish was low for site exposures and not expected to increase blood lead much above market basket.** ATSDR calculated a 0.80, 0.38, or 1.9% chance of a

[4] In October 2021, CDC updated the blood lead reference value (BLRV) from 5 µg/dL to 3.5 µg/dL [CDC 2021]. However, lead models are not currently validated for levels below 5 µg/dL. Therefore, ATSDR uses 5 µg/dL in the models in our health evaluations until the updated BLRV of 3.5 µg/dL can be verified by EPA in their models.
CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard. States independently determine action thresholds based on state laws, regulations, and resource availability. CDC encourages healthcare providers and public health professionals to follow the recommended follow-up actions based on confirmed blood lead levels (https://www.cdc.gov/nceh/lead/advisory/acclpp/actions-blls.htm).

blood lead above 5 µg/dL for a child eating clams one day a week, cockles one day a week, or both (each once in a week), respectively.

Table D7. IEUBK assumptions and predicted child blood lead levels (ages 1–7 years) from eating clams and cockles on a traditional diet, Former Treadwell Mine Complex, Douglas, AK.

Meat in diet	**Average Lead Concentration in Site Shellfish (µg lead/g food)**	**Number of Meals Per Year (meals per week)**	**Percent of total meat intake on traditional diet***	**IEUBK output from children eating traditional diet** (geomean and percent of children with blood lead predicted above 5 µg/dL) †
No site shellfish (site sediment only)	Default market basket values	Age-specific values	0%	1.154 (geomean) 0.091 % above
Clam	0.241	50 (~1 per week)	14% (one day per week)	1.613 (geomean) 0.804 % above
Cockle	0.145	53 (~1 per week)	14% (one day per week)	1.428 (geomean) 0.383 % above
Clam and Cockle	0.195‡	103 (~1 of each per week)	28% (each once per week)	1.889 (geomean) 1.916% above

Source: [ADEC 2015]; Hoonah diet [Sill 2017a]; [EPA 2021]

Notes: Used integrated exposure uptake biokinetic (IEUBK) model version 2.0 build 1.66;

*Adjusted the dietary values in the diet parameter using site-specific weighted average shellfish concentrations for clam and cockles assuming a meal one day per week as described for the Traditional Diet Scenario. Used the default of 30% bioavailability. Changed the default soil (sediment) concentration to 11.4 ppm lead.

†IEUBK is validated down to 5 µg/dL. In October 2021, CDC updated the blood lead reference value (BLRV) from 5 µg/dL to 3.5 µg/dL [CDC 2021]. However, lead models are not currently validated for levels below 5 µg/dL. Therefore, ATSDR uses 5 µg/dL in the models in our health evaluations until the updated BLRV of 3.5 µg/dL can be verified by EPA in their models. CDC's BLRV is a screening tool to identify children who have higher levels of lead in their blood compared with most children. The reference value is not health-based and is not a regulatory standard. States independently determine action thresholds based on state laws, regulations, and resource availability. CDC encourages healthcare providers and public health professionals to follow the recommended follow-up actions based on confirmed blood lead levels (https://www.cdc.gov/nceh/lead/advisory/acclpp/actions-blls.htm).

‡Used an average concentration for clams and cockles weighted by their intake frequency.

In conclusion, children's exposures to lead at the site do not increase their blood lead levels appreciably, relative to blood lead levels resulting from exposure to background levels of lead in soil and U. S. market basket levels of lead in meat.

Figure D3. Model output (IEUBK version 2) of the distribution probability of blood lead concentrations (µg/dL) for a child playing at the beach for at least 90 days or more assuming an average sediment lead concentration of 11.4 ppm

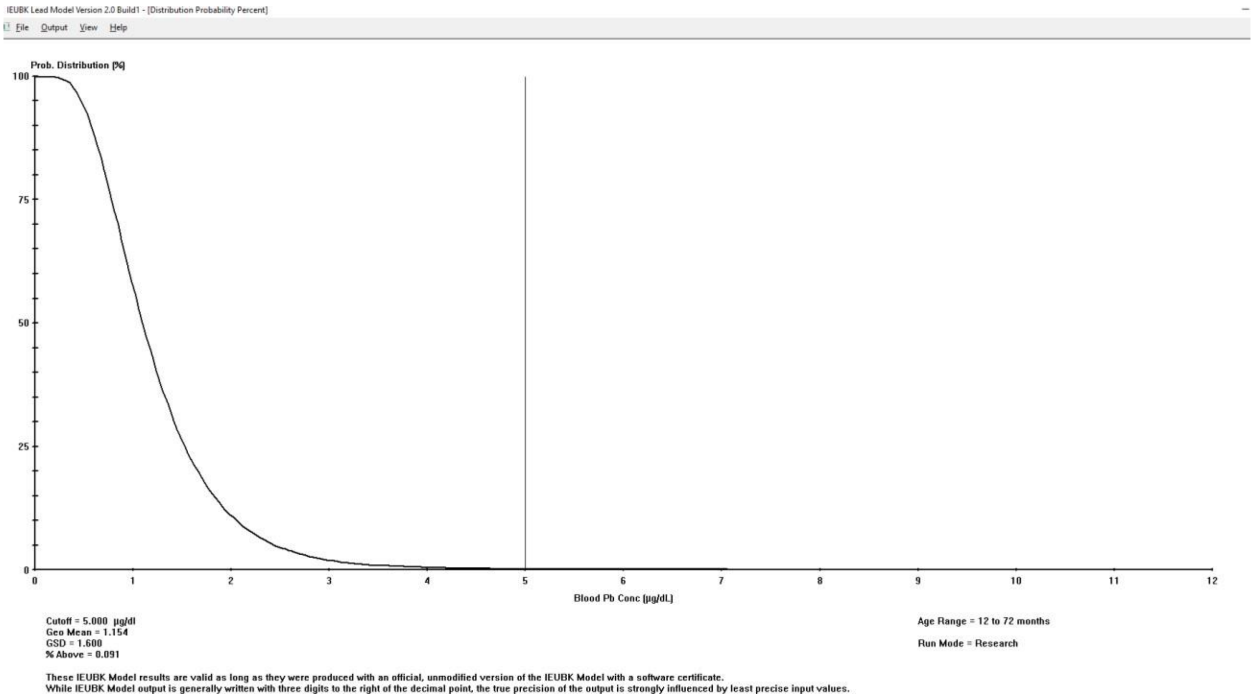


Figure D4. Model output (IEUBK version 2) of the distribution probability of blood lead concentrations (ug/dL) for a child consuming a clam meal one day a week, former Treadwell Mine Complex, Douglas, Alaska

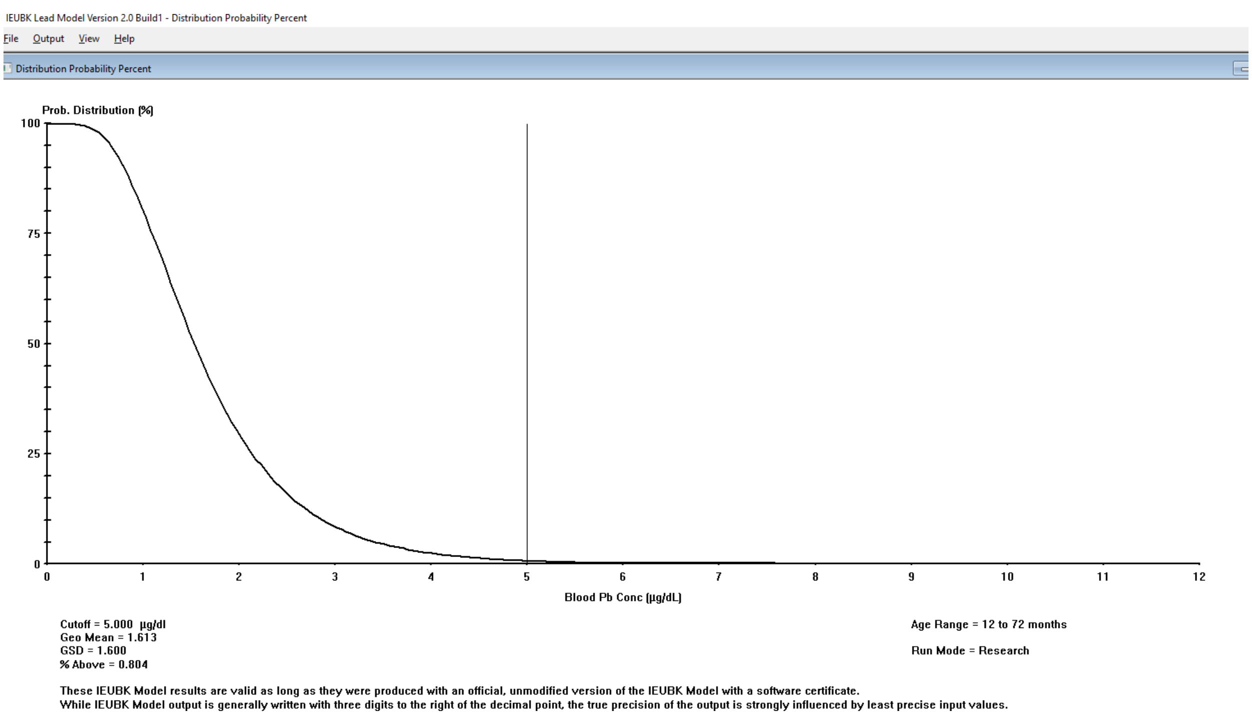


Figure D5. Model output (IEUBK version 2) of the distribution probability of blood lead concentrations (ug/dL) for a child consuming a cockle meal one day a week, Former Treadwell Mine Complex, Douglas, Alaska

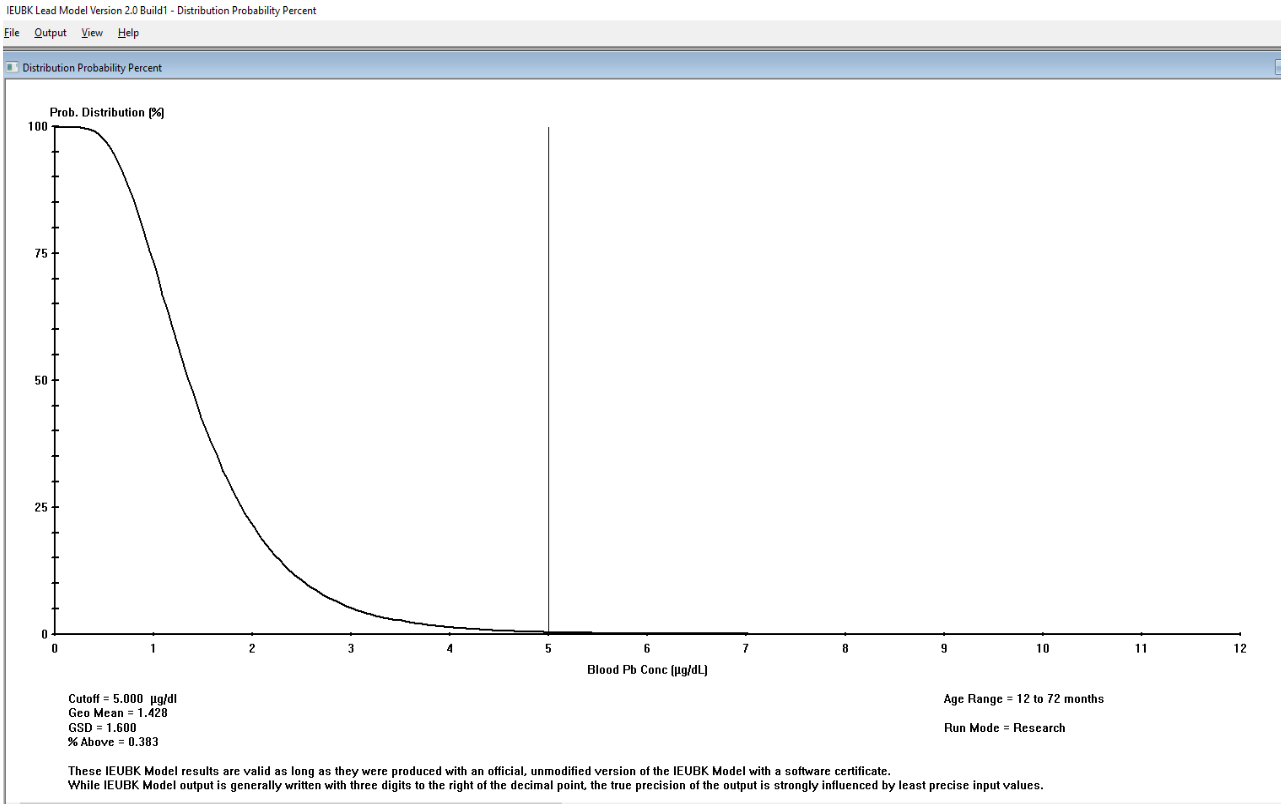
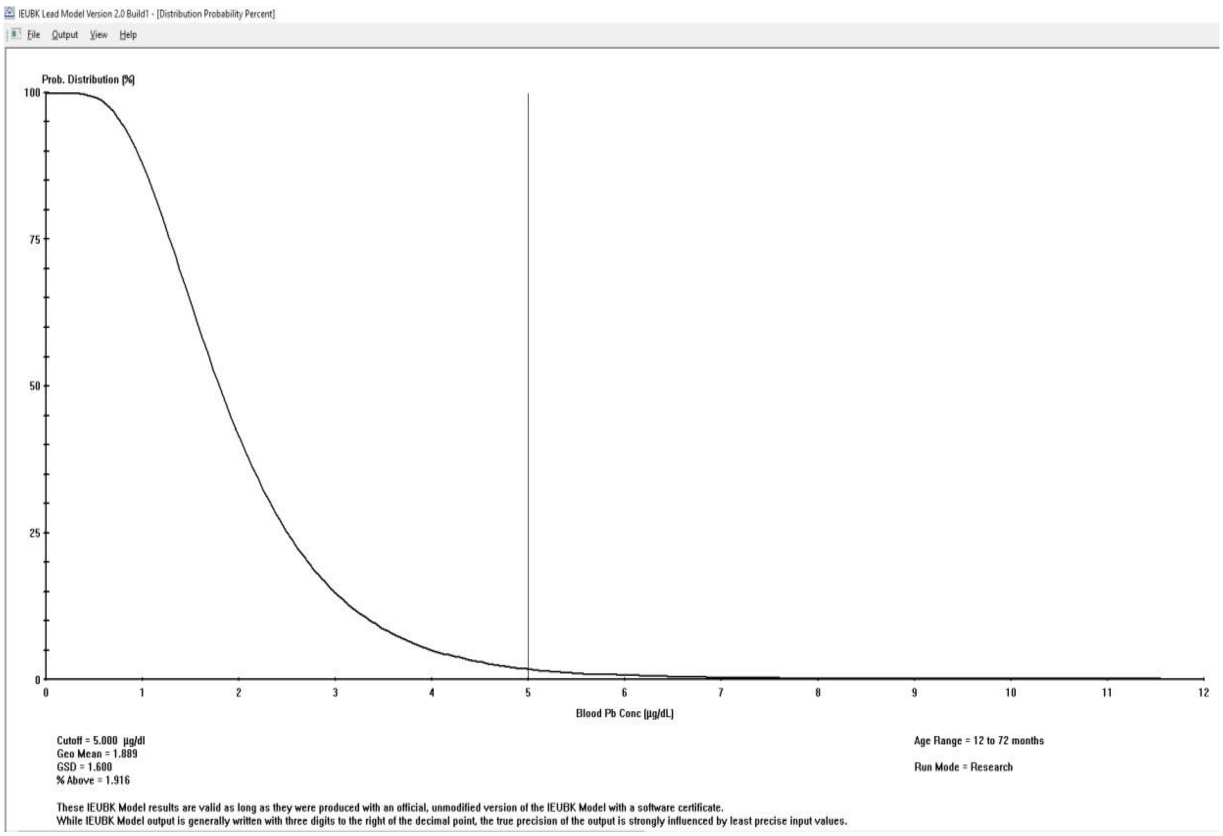


Figure D6. Model output (IEUBK version 2) of the distribution probability of blood lead concentrations (µg/dL) for a child consuming a clam meal plus a cockle meal, one each per week, Former Treadwell Mine Complex, Douglas, Alaska



Appendix E Model Output for all Health Risk Calculations

Appendix E contains model outputs from the public health assessment site tool (PHAST) for the exposure assessment scenarios of exposures to shellfish near the Former Treadwell Mine Complex. Risk calculation tables include:

- Clams, traditional diet (Tables E1a to E1i)
- Cockles, traditional diet (Tables E2a to E2h)
- Crab, traditional diet (Tables E3a to E3c)
- Mussels, traditional diet (Tables E4a to E4i)
- Sea cucumbers, traditional diet (Tables E5a to E5h)
- Clams, one meal a month (Tables E6a to E6i)
- Cockles, one meal a month (Tables E7a to E7h)
- Crab, one meal a month (Tables E8a to E8c)
- Mussels, one meal a month (Table E9a to E9i)
- Sea cucumbers, one meal a month (E10a to E10h)
- Background clams, traditional diet (E11a)
- Background clams, one meal a month (E11b)

Risk calculations for consuming clams in a traditional diet

Tables E1a to E1i include results from calculating hazard quotients and excess lifetime cancer risks from consumption of clams from the former Treadwell Mine Complex Site in the traditional diet scenario. Traditional diet assumed to be similar to Hoonah harvest rates [Sill 2017a] at fifty-one 4-oz meals per year for children aged 2 to 11 years, and fifty-one 8-oz meals for older children and adults. Contaminants in clams were measured by DIA contractor and ADEC [Ridolfi 2014, ADEC 2015].

Table E1a. Site-specific exposure doses for chronic exposure to inorganic arsenic in clams at 1.224 mg/kg along with non-cancer hazard quotients and cancer risk estimates*. Traditional diet (Hoonah) scenario.**

PUBLIC HEALTH ASSESSMENT SITE TOOL PHAST Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.0011	3.7 †	-	4
6 to < 11 years	0.00061	2.0 †	-	5
11 to < 16 years	0.00068	2.3 †	-	5
16 to < 21 years	0.00054	1.8 †	-	5

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
Total Child	-	-	2.6E-4 ‡	19
Adult	0.00048	1.6 †	5.3E-4 ‡	57
Lifetime Cancer Risk			7.9 E-4‡	76

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**For samples where only total arsenic was measured, 51% was assumed to be inorganic arsenic based on Ridolfi sample
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E1b. Site-specific exposure doses for acute exposure to inorganic arsenic in clams at 1.224 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0080	1.6 †
6 to < 11 years	0.0044	0.87
11 to < 16 years	0.0049	0.98
16 to < 21 years	0.0039	0.78
Adult	0.0035	0.69

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**For samples where only total arsenic was measured, 51% was assumed to be inorganic arsenic based on Ridolfi sample
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

Table E1c. Site-specific exposure doses for chronic exposure to cadmium in clams at 0.112 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00010	1.0 †	-	4
6 to < 11 years	5.6E-05	0.56	-	5
11 to < 16 years	6.2E-05	0.62	-	5
16 to < 21 years	5.0E-05	0.50	-	5
Total Child	-	-	-	19
Adult	4.4E-05	0.44	-	57

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

Table E1d. Site-specific exposure doses for intermediate exposure to cadmium in clams at 0.112 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00010	0.21
6 to < 11 years	5.7E-05	0.11
11 to < 16 years	6.4E-05	0.13
16 to < 21 years	5.1E-05	0.10
Adult	4.5E-05	0.091

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E1e. Site-specific exposure doses for intermediate exposure to copper in clams at 3.674 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0033	0.17
6 to < 11 years	0.0018	0.091
11 to < 16 years	0.0020	0.10
16 to < 21 years	0.0016	0.081
Adult	0.0014	0.072

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 3.7 mg/kg and intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E1f. Site-specific exposure doses for acute exposure to copper in clams at 3.674 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.024	1.2 †
6 to < 11 years	0.013	0.66
11 to < 16 years	0.015	0.73
16 to < 21 years	0.012	0.58
Adult	0.010	0.52

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food

* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 3.7 mg/kg and acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.
† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

Table E1g. Site-specific exposure doses for chronic exposure to selenium in clams at 1.334 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.0012	0.24	-	4
6 to < 11 years	0.00066	0.13	-	5
11 to < 16 years	0.00074	0.15	-	5
16 to < 21 years	0.00059	0.12	-	5
Total Child	-	-	-	19
Adult	0.00053	0.11	-	57

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Table E1h. Site-specific exposure doses for chronic exposure to methyl mercury in clams at 0.0227 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	2.0E-05	0.20	-	4
6 to < 11 years	1.1E-05	0.11	-	5
11 to < 16 years	1.3E-05	0.13	-	5
16 to < 21 years	1.0E-05	0.10	-	5
Total Child	-	-	-	19
Adult	8.9E-06	0.089	-	57

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 0.023 mg/kg and chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

**In 9 of 10 samples, only total mercury was measured. In those samples, we assumed all of the total mercury was in the methyl mercury form.

Table E1i. Site-specific exposure doses for chronic exposure to cyanide in clams at 0.02114 mg/kg along with non-cancer hazard quotients*. Traditional Diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	1.9E-05	0.031	-	4
6 to < 11 years	1.1E-05	0.017	-	5
11 to < 16 years	1.2E-05	0.019	-	5
16 to < 21 years	9.4E-06	0.015	-	5
Total Child	-	-	-	19
Adult	8.4E-06	0.013	-	57

Source: Clam data from Ridolfi 2014; ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce

Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (lifetime) reference dose of 0.00063 mg/kg/day.

Risk calculations for consuming cockles on a traditional diet

Table E2a to E2h include results from calculating hazard quotients and excess lifetime cancer risks for consumption of cockles from the former Treadwell Mine Complex Site at Traditional Diet consumption rates. The traditional diet was assumed to be similar to the Hoonah harvest rates [Sill 2017a] of fifty-three 4-oz meals per year for children aged 2 to 11 years, and fifty-three 8-oz meals for older children and adults. Environmental data were collected by ADEC [ADEC 2015].

Table E2a. Site-specific exposure doses for chronic exposure to inorganic arsenic in cockles at 0.16 mg/kg along with non-cancer hazard quotients and cancer risk estimates*. Traditional Diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00015	0.50	-	4
6 to < 11 years	8.2E-05	0.27	-	5
11 to < 16 years	9.1E-05	0.30	-	5
16 to < 21 years	7.2E-05	0.24	-	5
Total Child	-	-	3.5E-5 ‡	19
Adult	6.5E-05	0.22	7.1E-5 ‡	57
Lifetime Cancer Risk			1.1E-4	76

Source: Cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E2b. Site-specific exposure doses for acute exposure to inorganic arsenic in cockles at 0.16 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0010	0.21
6 to < 11 years	0.00057	0.11
11 to < 16 years	0.00064	0.13
16 to < 21 years	0.00051	0.10
Adult	0.00045	0.091

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.

Table E2c. Site-specific exposure doses for chronic exposure to cadmium in cockles at 0.069 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	6.4E-05	0.64	-	4
6 to < 11 years	3.5E-05	0.35	-	5
11 to < 16 years	3.9E-05	0.39	-	5
16 to < 21 years	3.1E-05	0.31	-	5
Total Child	-	-	-	19
Adult	2.8E-05	0.28	-	57

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E2d. Site-specific exposure doses for intermediate exposure to cadmium in cockles at 0.069 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	6.4E-05	0.13
6 to < 11 years	3.5E-05	0.070
11 to < 16 years	3.9E-05	0.079
16 to < 21 years	3.1E-05	0.062
Adult	2.8E-05	0.056

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E2e. Site-specific exposure doses for intermediate exposure to copper in cockles at 0.96 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00089	0.045
6 to < 11 years	0.00049	0.024
11 to < 16 years	0.00055	0.027
16 to < 21 years	0.00043	0.022
Adult	0.00039	0.019

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E2f. Site-specific exposure doses for acute exposure to copper in cockles at 0.96 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0063	0.31
6 to < 11 years	0.0034	0.17
11 to < 16 years	0.0038	0.19
16 to < 21 years	0.0030	0.15
Adult	0.0027	0.14

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.

Table E2g. Site-specific exposure doses for chronic exposure to selenium in cockles at 1.3 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.0012	0.24	-	4
6 to < 11 years	0.00066	0.13	-	5
11 to < 16 years	0.00074	0.15	-	5
16 to < 21 years	0.00059	0.12	-	5
Total Child	-	-	-	19
Adult	0.00053	0.11	-	57

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Table E2h. **Site-specific exposure doses for chronic exposure to methyl mercury** in cockles at 0.028 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	2.6E-05	0.26	-	4
6 to < 11 years	1.4E-05	0.14	-	5
11 to < 16 years	1.6E-05	0.16	-	5
16 to < 21 years	1.3E-05	0.13	-	5
Total Child	-	-	-	19
Adult	1.1E-05	0.11	-	57

Source: cockle data: ADEC 2015. Hoonah consumption rate source: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.
** Only total mercury was measured. We assumed all the mercury was in the methyl mercury form.

Risk calculations for consuming crabs on a traditional diet

Tables E3a to E3c include hazard quotients and excess lifetime cancer risk calculations from consumption of dungeness crab from the former Treadwell Mine Complex Site at traditional diet consumption rates. The traditional diet scenario is based on Hoonah harvest rate [Sill 2017a] of twenty-two 4-oz meals per year for children aged 2 to 11 and twenty-two 8-oz meals for older children and adults. DIA contractor provided crab data [Ridolfi 2014].

Table E3a. Site-specific exposure doses for chronic exposure to inorganic arsenic in Dungeness Crab at 0.04 mg/kg along with non-cancer hazard quotients and cancer risk estimates*. Traditional Diet (Hoonah) scenario.***

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	1.6E-05	0.052	-	4
6 to < 11 years	8.6E-06	0.029	-	5
11 to < 16 years	9.6E-06	0.032	-	5
16 to < 21 years	7.6E-06	0.025	-	5
Total Child	-	-	3.7E-6 ‡	19
Adult	6.8E-06	0.023	7.5E-6 ‡	57
Lifetime Cancer Risk			1.1E-5	76

Source: Crab data Ridolfi 2014. Hoonah consumption rate: Sill 2017a.

Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years

Notes:

* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.

**Actual inorganic arsenic measured in speciated analysis.

‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E3b. Site-specific exposure doses for acute exposure to inorganic arsenic in Dungeness Crab at 0.04 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00026	0.052
6 to < 11 years	0.00014	0.029
11 to < 16 years	0.00016	0.032
16 to < 21 years	0.00013	0.025
Adult	0.00011	0.023

Source: Crab data Ridolfi 2014. Hoonah consumption rate: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Actual inorganic arsenic measured in speciated analysis.

Table E3c. Site-specific exposure doses for chronic exposure to methyl mercury in Dungeness Crab at 0.0385 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	1.5E-05	0.15	-	4
6 to < 11 years	8.3E-06	0.083	-	5
11 to < 16 years	9.3E-06	0.093	-	5
16 to < 21 years	7.4E-06	0.074	-	5
Total Child	-	-	-	19
Adult	6.6E-06	0.066	-	57

Source: Crab data Ridolfi 2014. Hoonah consumption rate: Sill 2017a.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 0.039 mg/kg and chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

** Actual methyl mercury measurement from speciated analysis.

Risk calculations for consuming mussels on a traditional diet

Tables E4a to E4i include results from calculating hazard quotients and excess lifetime cancer risks from consumption of mussels collected near the former Treadwell Mine Complex Site in a traditional diet scenario. Traditional diet consumption rates are similar to Hoonah harvest rates [Sill 2017a] of two 4-oz meals per year for children aged 2 to 11 years and two 8-oz meals for older children and adults. Mussel data provided by ADEC [ADEC2015].

Table E4a. Site-specific exposure doses for chronic exposure to inorganic arsenic in mussels at 0.174 mg/kg along with non-cancer hazard quotients and cancer risk estimates*. Traditional Diet (Hoonah) scenario.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	6.2E-06	0.021	-	4
6 to < 11 years	3.4E-06	0.011	-	5
11 to < 16 years	3.8E-06	0.013	-	5
16 to < 21 years	3.0E-06	0.010	-	5
Total Child	-	-	1.5E-6 ‡	19
Adult	2.7E-06	0.0090	3.0E-6 ‡	57
Lifetime Cancer Risk			4.5E-6‡	76

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E4b. Site-specific exposure doses for acute exposure to inorganic arsenic in mussels at 0.174 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0011	0.23
6 to < 11 years	0.00062	0.12
11 to < 16 years	0.00069	0.14
16 to < 21 years	0.00055	0.11
Adult	0.00049	0.099

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.

Table E4c. Site-specific exposure doses for chronic exposure to cadmium in mussels at 0.444 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	1.6E-05	0.16	-	4
6 to < 11 years	8.7E-06	0.087	-	5
11 to < 16 years	9.7E-06	0.097	-	5
16 to < 21 years	7.7E-06	0.077	-	5
Total Child	-	-	-	19
Adult	6.9E-06	0.069	-	57

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E4d. Site-specific exposure doses for intermediate exposure to cadmium in mussels at 0.444 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00041	0.83
6 to < 11 years	0.00023	0.45
11 to < 16 years	0.00025	0.51
16 to < 21 years	0.00020	0.40
Adult	0.00018	0.36

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E4e. Site-specific exposure doses for intermediate exposure to copper in mussels at 1.32 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0012	0.061
6 to < 11 years	0.00067	0.034
11 to < 16 years	0.00075	0.038
16 to < 21 years	0.00060	0.030
Adult	0.00053	0.027

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 1.3 mg/kg and intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E4f. Site-specific exposure doses for acute exposure to copper in mussels at 1.32 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0086	0.43
6 to < 11 years	0.0047	0.24
11 to < 16 years	0.0053	0.26
16 to < 21 years	0.0042	0.21
Adult	0.0037	0.19

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 1.3 mg/kg and acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.

Table E4g. Site-specific exposure doses for chronic exposure to methyl mercury in mussels at 0.019 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	6.8E-07	0.0068	-	4
6 to < 11 years	3.7E-07	0.0037	-	5
11 to < 16 years	4.2E-07	0.0042	-	5
16 to < 21 years	3.3E-07	0.0033	-	5
Total Child	-	-	-	19
Adult	3.0E-07	0.0030	-	57

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

** Only total mercury was measured. We assumed all the mercury was in the methyl mercury form.

Table E4h. Site-specific exposure doses for chronic exposure to selenium in mussels at 1.472 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	5.3E-05	0.011	-	4
6 to < 11 years	2.9E-05	0.0058	-	5
11 to < 16 years	3.2E-05	0.0064	-	5
16 to < 21 years	2.6E-05	0.0051	-	5
Total Child	-	-	-	19
Adult	2.3E-05	0.0046	-	57

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Table E4i. Site-specific exposure doses for chronic exposure to cyanide in mussels at 0.067 mg/kg along with non-cancer hazard quotients*. Traditional Diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	2.4E-06	0.0038	-	4
6 to < 11 years	1.3E-06	0.0021	-	5
11 to < 16 years	1.5E-06	0.0023	-	5
16 to < 21 years	1.2E-06	0.0018	-	5
Total Child	-	-	-	19
Adult	1.0E-06	0.0017	-	57

Source: Mussel data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (lifetime) reference dose of 0.00063 mg/kg/day.

Risk calculations for consuming sea cucumbers on a traditional diet

Table E5a to E5h includes results from calculating hazard quotients and excess lifetime cancer risks from consuming sea cucumbers from the former Treadwell Mine Complex in the traditional diet scenario. Traditional diet is similar to the Hoonah harvest rates [Sill 2017a] of one 4-oz meal per year for children aged 2 to 11 years and one 8-oz meal for older children and adults. Sea cucumber data provided by ADEC [ADEC 2015].

Table E5a. Site-specific exposure doses for chronic exposure to inorganic arsenic in Sea Cucumbers at 0.23 mg/kg along with non-cancer hazard quotients and cancer risk estimates*. Traditional Diet (Hoonah) scenario.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	4.1E-06	0.014	-	4
6 to < 11 years	2.2E-06	0.0075	-	5
11 to < 16 years	2.5E-06	0.0084	-	5
16 to < 21 years	2.0E-06	0.0067	-	5
Total Child	-	-	9.7E-7	19
Adult	1.8E-06	0.0060	2.0E-6 ‡	57
Lifetime Cancer Risk			3.0E-6‡	76

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E5b. Site-specific exposure doses for acute exposure to inorganic arsenic in Sea Cucumbers at 0.23 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0015	0.30
6 to < 11 years	0.00082	0.16
11 to < 16 years	0.00092	0.18
16 to < 21 years	0.00073	0.15
Adult	0.00065	0.13

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.

Table E5c. Site-specific exposure doses for chronic exposure to cadmium in Sea Cucumbers at 0.24 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	4.3E-06	0.043	-	4
6 to < 11 years	2.3E-06	0.023	-	5
11 to < 16 years	2.6E-06	0.026	-	5
16 to < 21 years	2.1E-06	0.021	-	5
Total Child	-	-	-	19
Adult	1.9E-06	0.019	-	57

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E5d. Site-specific exposure doses for intermediate exposure to cadmium in Sea Cucumbers at 0.24 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00022	0.45
6 to < 11 years	0.00012	0.24
11 to < 16 years	0.00014	0.27
16 to < 21 years	0.00011	0.22
Adult	9.7E-05	0.19

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E5e. Site-specific exposure doses for intermediate exposure to copper in Sea Cucumbers at 14 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.013	0.65
6 to < 11 years	0.0071	0.36
11 to < 16 years	0.0080	0.40
16 to < 21 years	0.0063	0.32
Adult	0.0057	0.28

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E5f. Site-specific exposure doses for acute exposure to copper in Sea Cucumbers at 14 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.091	4.6 †
6 to < 11 years	0.050	2.5 †
11 to < 16 years	0.056	2.8 †
16 to < 21 years	0.044	2.2 †
Adult	0.040	2.0 †

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

Table E5g. Site-specific exposure doses for chronic exposure to methyl mercury in Sea Cucumbers at 0.041 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	7.3E-07	0.0073	-	4
6 to < 11 years	4.0E-07	0.0040	-	5
11 to < 16 years	4.5E-07	0.0045	-	5
16 to < 21 years	3.6E-07	0.0036	-	5
Total Child	-	-	-	19
Adult	3.2E-07	0.0032	-	57

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:

* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.
** Only total mercury was measured. We assumed all the mercury was in the methyl mercury form.

Table E5h. Site-specific exposure doses for chronic exposure to selenium in Sea Cucumbers at 1.1 mg/kg along with non-cancer hazard quotients*. Traditional diet (Hoonah) scenario.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	2.0E-05	0.0039	-	4
6 to < 11 years	1.1E-05	0.0021	-	5
11 to < 16 years	1.2E-05	0.0024	-	5
16 to < 21 years	9.5E-06	0.0019	-	5
Total Child	-	-	-	19
Adult	8.5E-06	0.0017	-	57

Source: Sea cucumber data [ADEC 2015] and Hoonah consumption rate [Sill 2017a].
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Risk calculations for consuming clams one meal a month

Tables E6a to E6i include results from calculating hazard quotients and excess lifetime cancer risks from consumption of clams from the former Treadwell Mine Complex Site, at One Meal a Month over a Lifetime (4-oz meals for children aged 2 to 11 years; 8-oz meals for older children and adults). DIA and ADEC provided clam data [Ridolfi 2014, ADEC 2015]

Table E6a. Site-specific exposure doses for chronic exposure to inorganic arsenic in clams at 1.224 mg/kg along with non-cancer hazard quotients and cancer risk estimates*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00026	0.87	-	4
6 to < 11 years	0.00014	0.48	-	5
11 to < 16 years	0.00016	0.54	-	5
16 to < 21 years	0.00013	0.42	-	5
Total Child	-	-	6.2E-5 ‡	19
Adult	0.00011	0.38	1.3E-4 ‡	57
Lifetime Cancer Risk			1.9E-4‡	76

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
** For samples where only total arsenic was measured, 51% was assumed to be inorganic arsenic based on Ridolfi sample
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E6b. Site-specific exposure doses for acute exposure to inorganic arsenic in clams at 1.224 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0080	1.6 †
6 to < 11 years	0.0044	0.87
11 to < 16 years	0.0049	0.98
16 to < 21 years	0.0039	0.78
Adult	0.0035	0.69

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
** For samples where only total arsenic was measured, 51% was assumed to be inorganic arsenic based on Ridolfi sample
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

Table E6c. Site-specific exposure doses for chronic exposure to cadmium in clams at 0.112 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	2.4E-05	0.24	-	4
6 to < 11 years	1.3E-05	0.13	-	5
11 to < 16 years	1.5E-05	0.15	-	5
16 to < 21 years	1.2E-05	0.12	-	5
Total Child	-	-	-	19
Adult	1.0E-05	0.10	-	57

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E6d. Site-specific exposure doses for intermediate exposure to cadmium in clams at 0.112 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST PUBLIC HEALTH ASSESSMENT SITE TOOL Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00010	0.21
6 to < 11 years	5.7E-05	0.11
11 to < 16 years	6.4E-05	0.13
16 to < 21 years	5.1E-05	0.10
Adult	4.5E-05	0.091

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E6e. Site-specific exposure doses for intermediate exposure to copper in clams at 3.674 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST PUBLIC HEALTH ASSESSMENT SITE TOOL Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0034	0.17
6 to < 11 years	0.0019	0.093
11 to < 16 years	0.0021	0.10
16 to < 21 years	0.0017	0.083
Adult	0.0015	0.074

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 3.7 mg/kg and intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E6f. Site-specific exposure doses for acute exposure to copper in clams at 3.674 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.024	1.2 †
6 to < 11 years	0.013	0.65
11 to < 16 years	0.015	0.73
16 to < 21 years	0.012	0.58
Adult	0.010	0.52

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 3.7 mg/kg and acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.

† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

Table E6g. Site-specific exposure doses for chronic exposure to methyl mercury in clams at 0.0227 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	4.9E-06	0.049	-	4
6 to < 11 years	2.7E-06	0.027	-	5
11 to < 16 years	3.0E-06	0.030	-	5
16 to < 21 years	2.4E-06	0.024	-	5
Total Child	-	-	-	19
Adult	2.1E-06	0.021	-	33

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:

* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 0.023 mg/kg and chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.
**In 9 of 10 samples, only total mercury was measured. In those samples, we assumed all the total mercury was in the methyl mercury form.

Table E6h. Site-specific exposure doses for chronic exposure to selenium in clams at 1.334 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00029	0.057	-	4
6 to < 11 years	0.00016	0.031	-	5
11 to < 16 years	0.00018	0.035	-	5
16 to < 21 years	0.00014	0.028	-	5
Total Child	-	-	-	19
Adult	0.00012	0.025	-	57

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Table E6i. Site-specific exposure doses for chronic exposure to cyanide in clams at 0.02114 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	4.5E-06	0.0072	-	4
6 to < 11 years	2.5E-06	0.0039	-	5
11 to < 16 years	2.8E-06	0.0044	-	5
16 to < 21 years	2.2E-06	0.0035	-	5
Total Child	-	-	-	19
Adult	2.0E-06	0.0031	-	57

Source: Clam data [Ridolfi 2014, ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (lifetime) reference dose of 0.00063 mg/kg/day.

Risk calculations for consuming cockles one meal a month

Table E7a to E7h include results from calculating hazard quotients and excess lifetime cancer risks from consumption of cockles from the former Treadwell Mine Complex Site, at one meal a month over a lifetime (4-oz meals for children aged 2 to 11 years; 8-oz meals for older children and adults). ADEC provided cockle data [ADEC 2015].

Table E7a. Site-specific exposure doses for chronic exposure to inorganic arsenic in cockles at 0.16 mg/kg along with non-cancer hazard quotients and cancer risk estimates*, at One Meal Per Month over a Lifetime.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	3.4E-05	0.11	-	4
6 to < 11 years	1.9E-05	0.063	-	5
11 to < 16 years	2.1E-05	0.070	-	5
16 to < 21 years	1.7E-05	0.056	-	5
Total Child	-	-	8.1E-6 ‡	19
Adult	1.5E-05	0.050	1.6E-5 ‡	57
Lifetime Cancer Risk			2.4E-5‡	76

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E7b. Site-specific exposure doses for acute exposure to inorganic arsenic in cockles at 0.16 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0010	0.21
6 to < 11 years	0.00057	0.11
11 to < 16 years	0.00064	0.13
16 to < 21 years	0.00051	0.10
Adult	0.00045	0.091

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.

Table E7c. Site-specific exposure doses for chronic exposure to cadmium in cockles at 0.069 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	1.5E-05	0.15	-	4
6 to < 11 years	8.1E-06	0.081	-	5
11 to < 16 years	9.1E-06	0.091	-	5
16 to < 21 years	7.2E-06	0.072	-	5
Total Child	-	-	-	19
Adult	6.4E-06	0.064	-	57

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E7d. Site-specific exposure doses for intermediate exposure to cadmium in cockles at 0.069 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	6.4E-05	0.13
6 to < 11 years	3.5E-05	0.070
11 to < 16 years	3.9E-05	0.079
16 to < 21 years	3.1E-05	0.062
Adult	2.8E-05	0.056

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E7e. Site-specific exposure doses for intermediate exposure to copper in cockles at 0.96 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00089	0.045
6 to < 11 years	0.00049	0.024
11 to < 16 years	0.00055	0.027
16 to < 21 years	0.00043	0.022
Adult	0.00039	0.019

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E7f. Site-specific exposure doses for acute exposure to copper in cockles at 0.96 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0063	0.31
6 to < 11 years	0.0034	0.17
11 to < 16 years	0.0038	0.19
16 to < 21 years	0.0030	0.15
Adult	0.0027	0.14

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.

Table E7g. Site-specific exposure doses for chronic exposure to methyl mercury in cockles at 0.028 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	6.0E-06	0.060	-	4
6 to < 11 years	3.3E-06	0.033	-	5
11 to < 16 years	3.7E-06	0.037	-	5
16 to < 21 years	2.9E-06	0.029	-	5
Total Child	-	-	-	19
Adult	2.6E-06	0.026	-	57

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

** Only total mercury was measured. We assumed all the mercury was in the methyl mercury form.

Table E7h. Site-specific exposure doses for chronic exposure to selenium in cockles at 1.3 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00028	0.056	-	4
6 to < 11 years	0.00015	0.030	-	5
11 to < 16 years	0.00017	0.034	-	5
16 to < 21 years	0.00014	0.027	-	5
Total Child	-	-	-	19
Adult	0.00012	0.024	-	57

Source: Cockle data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Risk calculations for consuming crabs one meal a month

Table E8a to E8c include results from calculating hazard quotients and excess lifetime cancer risks from consumption of Dungeness crabs from the former Treadwell Mine Complex Site, at one meal a month over a lifetime (4-oz meals for children aged 2 to 11 years; 8-oz meals for older children and adults). DIA provided Dungeness crab data [Ridolfi 2014].

Table E8a. Site-specific exposure doses for chronic exposure to inorganic arsenic in Dungeness Crabs at 0.04 mg/kg along with non-cancer hazard quotients and cancer risk estimates*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	8.6E-06	0.029	-	4
6 to < 11 years	4.7E-06	0.016	-	5
11 to < 16 years	5.3E-06	0.018	-	5
16 to < 21 years	4.2E-06	0.014	-	5
Total Child	-	-	2.0E-6 ‡	19
Adult	3.7E-06	0.012	4.1E-6 ‡	57
Lifetime Cancer Risk			6.1E-6‡	76

Source: Crab data [Ridolfi 2014]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
** Actual inorganic arsenic measured in speciated analysis.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E8b. Site-specific exposure doses for acute exposure to inorganic arsenic in Dungeness Crabs at 0.04 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00026	0.052
6 to < 11 years	0.00014	0.029
11 to < 16 years	0.00016	0.032
16 to < 21 years	0.00013	0.025
Adult	0.00011	0.023

Source: Crab data [Ridolfi 2014]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Actual inorganic arsenic measured in speciated analysis.

Table E8c. Site-specific exposure doses for chronic exposure to methyl mercury in Dungeness Crabs at 0.0385 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	8.2E-06	0.082	-	4
6 to < 11 years	4.5E-06	0.045	-	5
11 to < 16 years	5.1E-06	0.051	-	5
16 to < 21 years	4.0E-06	0.040	-	5
Total Child	-	-	-	19
Adult	3.6E-06	0.036	-	57

Source: Crab data [Ridolfi 2014]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:

* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 0.039 mg/kg and chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.
** Actual methyl mercury measurement from speciated analysis.

Risk calculations from consuming mussels one meal a month

Table E9a to E9i includes results from calculating hazard quotients and excess lifetime cancer risks from consumption of mussels from the former Treadwell Mine Complex Site, at one meal a month over a lifetime (4-oz meals for children aged 2 to 11 years; 8-oz meals for older children and adults). ADEC provided mussel data [ADEC 2015].

Table E9a. Site-specific exposure doses for chronic exposure to inorganic arsenic in mussels at 0.174 mg/kg along with non-cancer hazard quotients and cancer risk estimates*, at One Meal Per Month over a Lifetime.**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	3.7E-05	0.12	-	4
6 to < 11 years	2.0E-05	0.068	-	5
11 to < 16 years	2.3E-05	0.076	-	5
16 to < 21 years	1.8E-05	0.060	-	5
Total Child	-	-	8.8E-6 ‡	19
Adult	1.6E-05	0.054	1.8E-5 ‡	57
Lifetime Cancer Risk			2.7E-5‡	76

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E9b. Site-specific exposure doses for acute exposure to inorganic arsenic in mussels at 0.174 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0011	0.23
6 to < 11 years	0.00062	0.12
11 to < 16 years	0.00069	0.14
16 to < 21 years	0.00055	0.11
Adult	0.00049	0.099

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.

Table E9c. Site-specific exposure doses for chronic exposure to cadmium in mussels at 0.444 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	9.5E-05	0.95	-	4
6 to < 11 years	5.2E-05	0.52	-	5
11 to < 16 years	5.8E-05	0.58	-	5
16 to < 21 years	4.6E-05	0.46	-	5
Total Child	-	-	-	19
Adult	4.1E-05	0.41	-	57

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E9d. Site-specific exposure doses for intermediate exposure to cadmium in mussels at 0.444 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00041	0.83
6 to < 11 years	0.00023	0.45
11 to < 16 years	0.00025	0.51
16 to < 21 years	0.00020	0.40
Adult	0.00018	0.36

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E9e. Site-specific exposure doses for intermediate exposure to copper in mussels at 1.32 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0012	0.061
6 to < 11 years	0.00067	0.034
11 to < 16 years	0.00075	0.038
16 to < 21 years	0.00060	0.030
Adult	0.00053	0.027

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 1.3 mg/kg and intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E9f. Site-specific exposure doses for acute exposure to copper in mussels at 1.32 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0086	0.43
6 to < 11 years	0.0047	0.24
11 to < 16 years	0.0053	0.26
16 to < 21 years	0.0042	0.21
Adult	0.0037	0.19

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the EPC: 1.3 mg/kg and acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.

Table E9g. Site-specific exposure doses for chronic exposure to methyl mercury in mussels at 0.019 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	4.1E-06	0.041	-	4
6 to < 11 years	2.2E-06	0.022	-	5
11 to < 16 years	2.5E-06	0.025	-	5
16 to < 21 years	2.0E-06	0.020	-	5
Total Child	-	-	-	19
Adult	1.8E-06	0.018	-	57

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

** Only total mercury was measured. We assumed all the mercury was in the methyl mercury form.

Table E9h. Site-specific exposure doses for chronic exposure to selenium in mussels at 1.472 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00032	0.063	-	4
6 to < 11 years	0.00017	0.035	-	5
11 to < 16 years	0.00019	0.039	-	5
16 to < 21 years	0.00015	0.031	-	5
Total Child	-	-	-	19
Adult	0.00014	0.027	-	57

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Table E9i. Site-specific exposure doses for chronic exposure to cyanide in mussels at 0.067 mg/kg along with non-cancer hazards*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	1.4E-05	0.023	-	4
6 to < 11 years	7.9E-06	0.012	-	5
11 to < 16 years	8.8E-06	0.014	-	5
16 to < 21 years	7.0E-06	0.011	-	5
Total Child	-	-	-	19
Adult	6.2E-06	0.0099	-	57

Source: Mussel data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (lifetime) reference dose of 0.00063 mg/kg/day.

Risk calculations for consuming sea cucumbers at one meal a month

Table E10a to E10h includes results from calculating hazard quotients and excess lifetime cancer risks from consumption of sea cucumbers from the former Treadwell Mine Complex Site, at one meal a month over a lifetime (4-oz meals for children aged 2 to 11 years; 8-oz meals for older children and adults). ADEC provided sea cucumber data [ADEC 2015].

Table E10a. Site-specific exposure doses for chronic exposure to inorganic arsenic in Sea Cucumbers at 0.23 mg/kg along with non-cancer hazard quotients and cancer risk estimates*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	4.9E-05	0.16	-	4
6 to < 11 years	2.7E-05	0.090	-	5
11 to < 16 years	3.0E-05	0.10	-	5
16 to < 21 years	2.4E-05	0.080	-	5
Total Child	-	-	1.2E-5 ‡	19
Adult	2.1E-05	0.071	2.3E-5 ‡	57
Lifetime Cancer Risk			3.5E-5‡	76

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
** Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E10b. Site-specific exposure doses for acute exposure to inorganic arsenic in Sea Cucumbers at 0.23 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.0015	0.30
6 to < 11 years	0.00082	0.16
11 to < 16 years	0.00092	0.18
16 to < 21 years	0.00073	0.15
Adult	0.00065	0.13

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.005 mg/kg/day.
**Only total arsenic was measured. We assumed that 10% of the arsenic was in an inorganic form.

Table E10c. Site-specific exposure doses for chronic exposure to cadmium in Sea Cucumbers at 0.24 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	5.1E-05	0.51	-	4
6 to < 11 years	2.8E-05	0.28	-	5
11 to < 16 years	3.2E-05	0.32	-	5
16 to < 21 years	2.5E-05	0.25	-	5
Total Child	-	-	-	19
Adult	2.2E-05	0.22	-	57

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.

Table E10d. Site-specific exposure doses for intermediate exposure to cadmium in Sea Cucumbers at 0.24 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.00022	0.45
6 to < 11 years	0.00012	0.24
11 to < 16 years	0.00014	0.27
16 to < 21 years	0.00011	0.22
Adult	9.7E-05	0.19

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.0005 mg/kg/day.

Table E10e. Site-specific exposure doses for intermediate exposure to copper in Sea Cucumbers at 14 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.013	0.65
6 to < 11 years	0.0071	0.36
11 to < 16 years	0.0080	0.40
16 to < 21 years	0.0063	0.32
Adult	0.0057	0.28

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the intermediate (two weeks to less than 1 year) minimal risk level of 0.02 mg/kg/day.

Table E10f. Site-specific exposure doses for acute exposure to copper in Sea Cucumbers at 14 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient
2 to < 6 years	0.091	4.6 †
6 to < 11 years	0.050	2.5 †
11 to < 16 years	0.056	2.8 †
16 to < 21 years	0.044	2.2 †
Adult	0.040	2.0 †

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:
* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the acute (less than two weeks) minimal risk level of 0.02 mg/kg/day.
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.

Table E10g. Site-specific exposure doses for chronic exposure to methyl mercury in Sea Cucumbers at 0.041 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration (yrs.)
2 to < 6 years	8.8E-06	0.088	-	4
6 to < 11 years	4.8E-06	0.048	-	5
11 to < 16 years	5.4E-06	0.054	-	5
16 to < 21 years	4.3E-06	0.043	-	5
Total Child	-	-	-	19
Adult	3.8E-06	0.038	-	57

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food
Notes:

* The calculations in this table were generated using ATSDR's PHAST v2.2.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0001 mg/kg/day.
** Only total mercury was measured. We assumed all the mercury was in the methyl mercury form.

Table E10h. Site-specific exposure doses for chronic exposure to selenium in Sea Cucumbers at 1.1 mg/kg along with non-cancer hazard quotients*, at One Meal Per Month over a Lifetime.

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00024	0.047	-	4
6 to < 11 years	0.00013	0.026	-	5
11 to < 16 years	0.00014	0.029	-	5
16 to < 21 years	0.00011	0.023	-	5
Total Child	-	-	-	19
Adult	0.00010	0.021	-	57

Source: Sea cucumber data [ADEC 2015]
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; oz = ounce; yrs. = years
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.005 mg/kg/day.

Background risk calculations for consuming clams in traditional diet

Table E11a and E11b include results for calculating hazard quotients and excess lifetime cancer risks from consumption of clams from Brown's Bay (Background Area in Southeast Alaska) collected during the Salt Chuck Mine Remedial Investigation [EPA 2018].

Table E11a. Background exposure doses for chronic exposure to inorganic arsenic in clams from Brown's Bay at 0.342 mg/kg along with non-cancer hazard quotients and cancer risk estimates*. Traditional Diet scenario (Hoonah Harvest Rate of Fifty One 4-oz meals per year for children aged 2 to 11, and Fifty One 8-oz meals per year for older children and adults).**

Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	0.00031	1.0 †	-	4
6 to < 11 years	0.00017	0.57	-	5
11 to < 16 years	0.00019	0.64	-	5
16 to < 21 years	0.00015	0.50	-	5
Total Child	-	-	7.3E-5 ‡	19
Adult	0.00014	0.45	1.5E-4 ‡	57
Lifetime Cancer Risk			2.2E-4‡	76

Source: Background clams are from Brown's Bay; Salt Chuck Mine Remedial investigation (n=21), EPA 2018.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; yrs. = years; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Actual inorganic arsenic measured in speciated analysis.
† A shaded cell indicates the hazard quotient exceeds the non-cancer health guideline, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

Table E11b. Background exposure doses for chronic exposure to inorganic arsenic in clams from Brown's Bay at 0.342 mg/kg along with non-cancer hazard quotients and cancer risk estimates*, at One Meal a Month over a Lifetime (4-oz meals for children aged 2 to 11 years; 8-oz meals for older children and adults)**

PHAST Public Health Assessment Site Tool Exposure Group	Dose (mg/kg/day)	Non-cancer Hazard Quotient	Cancer Risk	Exposure Duration for Cancer (yrs.)
2 to < 6 years	7.3E-05	0.24	-	4
6 to < 11 years	4.0E-05	0.13	-	5
11 to < 16 years	4.5E-05	0.15	-	5
16 to < 21 years	3.6E-05	0.12	-	5
Total Child	-	-	1.7E-5 ‡	19
Adult	3.2E-05	0.11	3.5E-5 ‡	57
Lifetime Cancer Risk			5.2E-5‡	76

Source: Background clams are from Brown's Bay; Salt Chuck Mine Remedial investigation (n=21), EPA 2018.
Abbreviations: mg/kg/day = milligram chemical per kilogram body weight per day; mg/kg = milligram chemical per kilogram food; yrs. = years; oz = ounce
Notes:
* The calculations in this table were generated using ATSDR's PHAST v1.7.1.0. The non-cancer hazard quotients were calculated using the chronic (greater than 1 year) minimal risk level of 0.0003 mg/kg/day and the cancer risks were calculated using the cancer slope factor of 1.5 $(mg/kg/day)^{-1}$.
**Actual inorganic arsenic measured in speciated analysis.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

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