

National Water-Quality Assessment Program

Distribution of Arsenic in Water and Streambed Sediments, Cook Inlet Basin, Alaska

Introduction

The Cook Inlet Basin (Fig. 1) encompasses 39,325 square miles in south-central Alaska. Abundant mineral resources, recent glaciation, and volcanic activity contribute to the widespread distribution of arsenic in the environment. More than half of Alaska's population reside in the basin, mostly in the Anchorage area. However, rapid growth is occurring in the Matanuska-Susitna and Kenai Peninsula Boroughs to the north and south of Anchorage. In 1997, a study of the Cook Inlet Basin was begun as part of the U.S. Geological Survey's National Water-Quality Assessment Program. A goal of this program is to describe the status of water quality and gain a better understanding of the natural and human factors that affect the water quality.

Why has arsenic been in the news recently?

Long-term exposure to high concentrations of arsenic in drinking water and food has been linked to bladder and lung cancer in humans. In 1999, the National Academy of Sciences concluded that the current standard of 50 micrograms per liter ($\mu\text{g/L}$) does not sufficiently protect public health. The U.S. Environmental Protection Agency revised the Maximum Contaminant Level (MCL) to 10 $\mu\text{g/L}$ during January 2001, but the revised standard was withdrawn during March 2001 pending further review. Studies of ground-water resources in the Cook Inlet Basin by the U.S. Geological Survey (USGS), the Alaska Department of Environmental Conservation, and the Municipality of Anchorage indicate that some domestic and public-supply wells yield water containing concentrations of arsenic that exceed the MCL of 50 $\mu\text{g/L}$.

Arsenic is a naturally occurring element in the environment. Its presence in ground water is the result of arsenic-bearing minerals dissolving naturally over time as certain types of rock and soils are weathered. Arsenic is present in both bedrock and unconsolidated-deposits aquifers within the Cook Inlet Basin

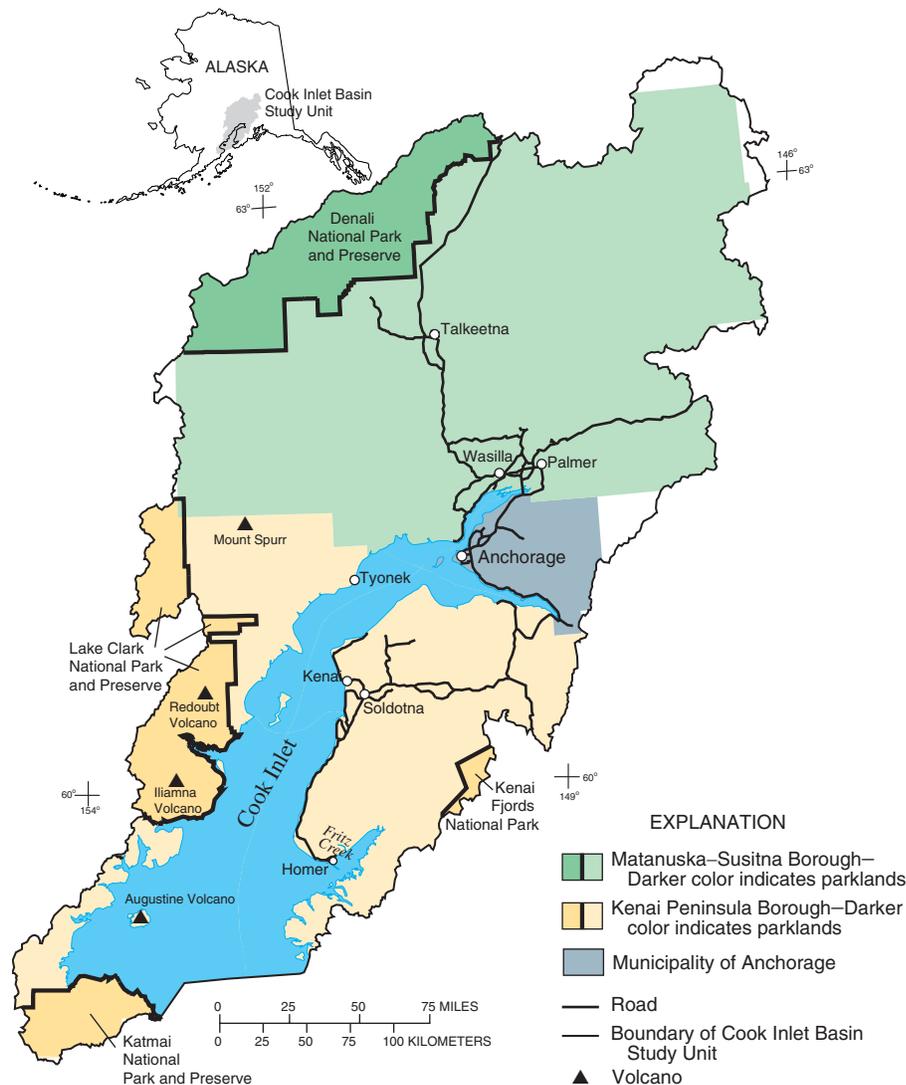


Figure 1. Boroughs and National Parks in the Cook Inlet Basin.

What are the sources of arsenic?

Arsenic is a naturally occurring element in the Earth's crust. Arsenic commonly is adsorbed to or coprecipitated with iron oxide minerals; adsorbed to clay-mineral surfaces; associated with sulfide minerals or organic carbon; and found in some types of volcanic rocks. Metal oxides and clay minerals are ubiquitous in the Cook Inlet Basin. Organic carbon, as peat and coal, is also widespread. Volcanic ash from several nearby active vol-

canoes has dusted the area. The natural dissolving or desorbing of arsenic from these source materials may introduce arsenic into the area's water. The uptake or release of arsenic by precipitation-dissolution and adsorption-desorption reactions is influenced by changes in pH, occurrence of oxidation-reductions reactions, and the chemical composition of the water, especially the presence of competing anions. Conditions that favor the release of arsenic to ground water include the presence of iron oxide and sulfide miner-

als in aquifer materials, alkaline ground water (pH greater than 7 units), and presence of phosphate and organic carbon. A chemically reduced environment may dissolve iron oxides and release arsenic.

The addition of arsenic to water in the Cook Inlet Basin by humans is minimal. More than 90 percent of the total use of arsenic in the U.S. is as a preservative in wood products. The total contribution of arsenic from treated wood to water in the Cook Inlet Basin probably is extremely small compared to the large amount of arsenic that occurs naturally in the area's rocks and soils. Other common uses of arsenic, such as application onto cotton and fruit orchards or as a feed additive for poultry and swine, are minimal in the basin.

What is the range of arsenic concentrations in drinking water?

Water samples collected for health-related purposes are collected after water treatment by homeowners or by suppliers of water. Reported concentrations of arsenic in Class-A public-water systems are commonly greater than 10 µg/L; water samples from more than 60 public-water systems in Cook Inlet Basin had arsenic concentrations greater than 10 µg/L (Keven Kleweno, Alaska Department of Environmental Conservation, written commun., 2000).

Many domestic and public-supply wells throughout the Cook Inlet Basin yield water having arsenic concentrations greater than the proposed MCL of 10 µg/L, but concentrations vary widely, even at a local scale (Fig. 2). The only way to be certain of the arsenic concentration in water supplied by a given well is to have the water tested. The health effects of arsenic depend on the concentration of arsenic in drinking water and the amount of water consumed.

Concerns about high levels of arsenic in ground water near Sand Lake in the western part of Anchorage brought about a sampling of water from 25 domestic wells by the Municipality of Anchorage's Department of Health and Human Services. Water samples were collected between December 2000 and March 2001 from faucets inside houses; many were collected after the water passes through water softeners and(or) filters. Concentrations were less than the detection level (1 µg/L) at 3 of the 25 sites but were as great as 89 µg/L. Tap water from 19 residences had concentrations of arsenic greater than 10 µg/L, 13 were greater than 24 µg/L. Drinking water from three houses had concentrations greater than the MCL of 50 µg/L.

What is the distribution of arsenic in ground water?

Ground water sampled by the USGS is collected before the water is treated by a homeowner or public-water system and represents the untreated ground-water resource itself, not the "finished" water used for drinking. Concentrations of dissolved arsenic in water samples collected by the USGS from 220 wells from 1969 through 1999 varied widely. Of the 220 wells sampled, 65 yielded dissolved-arsenic concentrations of 10 µg/L or greater, and 10 yielded values greater than 50 µg/L, the current MCL. The highest dissolved arsenic concentration recorded, 150 µg/L, was for a well on the west side of Cook Inlet that was perforated in a sand layer 63 to 68 feet below land surface and was also open

to sedimentary bedrock from 124 to 383 feet. A high degree of spatial variability in arsenic concentration was observed throughout the Cook Inlet Basin, even among wells within a single residential subdivision, because of local differences in geology, geochemistry, and aquifer conditions. Concentrations of dissolved arsenic greater than 10 µg/L did not appear to cluster in only a few locations but were scattered throughout the study area (Fig. 2). Most ground-water samples that contained high arsenic concentrations were from chemically reduced environments.

Low concentrations of arsenic are present in ground water from all aquifers in Cook Inlet Basin. About 67 percent of the 220 wells sampled had water containing dissolved arsenic at concentrations greater than 1 µg/L. About 30 percent had concentrations greater than 10 µg/L, and about 5 percent had concentrations greater than 50 µg/L. (See table, to right, and Fig. 3.)

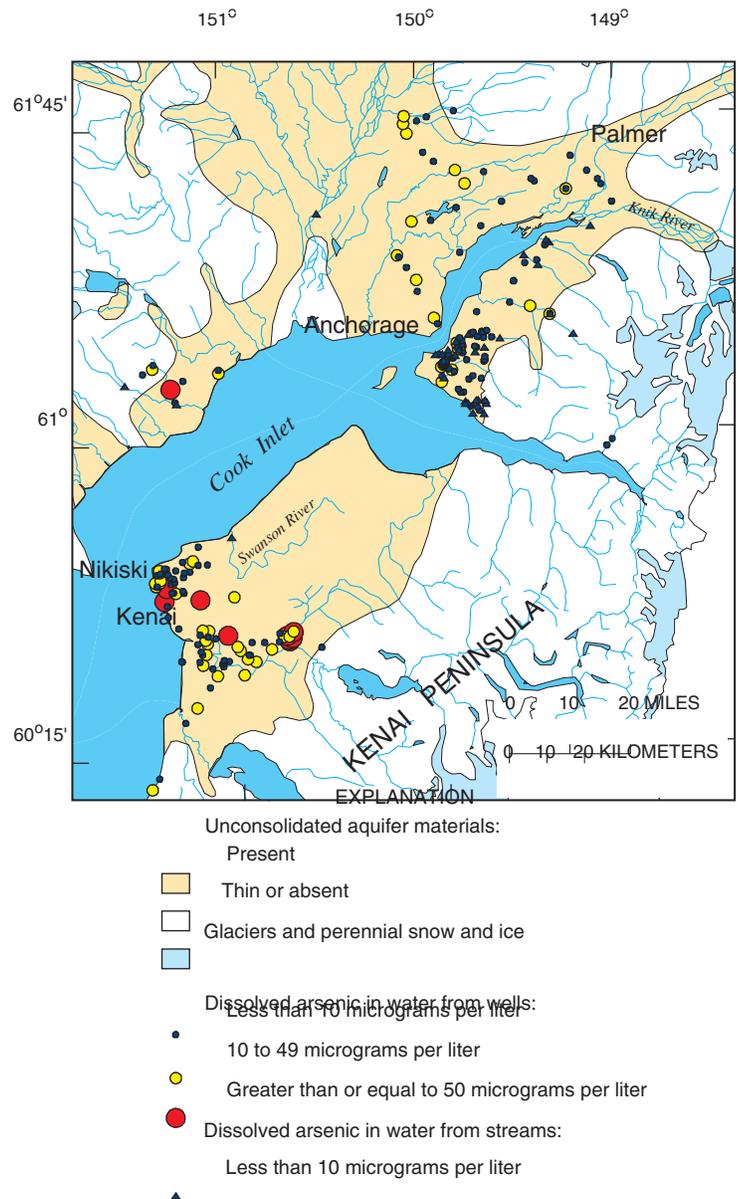


Figure 2. Spatial distribution of dissolved arsenic in selected wells and streams sampled by the U.S. Geological Survey.

Summary of dissolved arsenic in ground water sampled by U.S. Geological Survey in Cook Inlet Basin

[Detection limit for arsenic is 1 microgram per liter]

Borough	Number of wells sampled by U.S. Geological Survey	Median dissolved-arsenic concentration (micrograms per liter)	Percentage of samples having given concentrations	
			Less than 10 micrograms per liter	Less than 50 micrograms per liter
Municipality of Anchorage	76	1.5	83	100
Kenai Peninsula Borough ¹	109	5.0	60	91
Matanuska-Susitna Borough	35	2.0	71	100
Entire Cook Inlet Basin.....	220	3.0	70	95

¹Excluding Seward, which is not within Cook Inlet Basin.

Is arsenic commonly detected in surface water?

Although arsenic in surface water is derived primarily from the natural weathering of soils and rocks and from the discharge of ground water, detectable arsenic concentrations are uncommon in Cook Inlet Basin streams. Analyses of water samples collected by the USGS from 1969 through 2000 are available from several sites (some shown in Fig. 2) for water samples that were filtered by using a 0.45-micrometer filter (reported as “dissolved arsenic”) and water samples that were unfiltered (reported as “total arsenic”). Of the 58 surface-water sites having dissolved-arsenic analyses, 50 had concentrations that were at or less than the 1- $\mu\text{g/L}$ detection level. The highest dissolved-arsenic concentrations were observed at Fritz Creek near Homer (3 $\mu\text{g/L}$) and Swanson River near Kenai (9 $\mu\text{g/L}$). Concentrations of arsenic in unfiltered samples generally were higher than the filtered samples, probably owing to the arsenic associated with suspended sediment particles. The three sites having the highest total-arsenic concentrations were Knik River near Palmer (14 $\mu\text{g/L}$), Maclaren River near Paxson (18 $\mu\text{g/L}$), and a canal on the east side of Sand Lake in Anchorage (24 $\mu\text{g/L}$).

Is arsenic in streambed sediments harmful to aquatic life?

Elevated arsenic concentrations in streambed sediments may have adverse effects on organisms that live in the sediments or on the fish and wildlife that may feed on such organisms. A regulatory guideline for arsenic in streambed sediments currently does not exist for the United States. However, a guideline from the Canadian Council of Ministers of the Environment (1999) can be used for discussion. This guideline, called the Probable Effect Level (PEL), is the concentration above which adverse effects are expected to occur frequently. The PEL for arsenic is 17 micrograms per gram ($\mu\text{g/g}$), dry weight, for bulk (unsieved) sediments.

Streambed-sediment samples have been collected in the Cook Inlet Basin as part of the National Uranium Resource Evaluation (NURE) Hydrogeochemical and Streambed Sediment Reconnaissance program as well as for the NAWQA program and studies with the National Park Service (Fig. 4). Samples collected are sieved to fine-grained fractions prior to analysis (Fig. 5). Finer grained sediment samples tend to have higher concentrations of trace elements, including arsenic, than do bulk sediment samples. NURE samples were sieved to 0.150 millimeters and had arsenic concentrations from less than 5 to 184 $\mu\text{g/g}$, dry weight, in 94 samples collected in 1977. NAWQA samples and samples collected for the National Park Service (Fig. 4) were sieved to 0.063 mm and had arsenic concentrations from 1.7 to 88 $\mu\text{g/g}$ in samples collected from 47 sites during 1998 to 2000. Of the NURE samples, 54 percent had arsenic concentrations greater than the PEL, whereas 47 percent of the NAWQA samples exceeded the PEL.

—Roy L. Glass and Steven A. Frenzel

Concentrations of dissolved arsenic in Cook Inlet Basin streams are typically very low: About 90 percent of streams sampled have concentrations of 1 $\mu\text{g/L}$ or less.

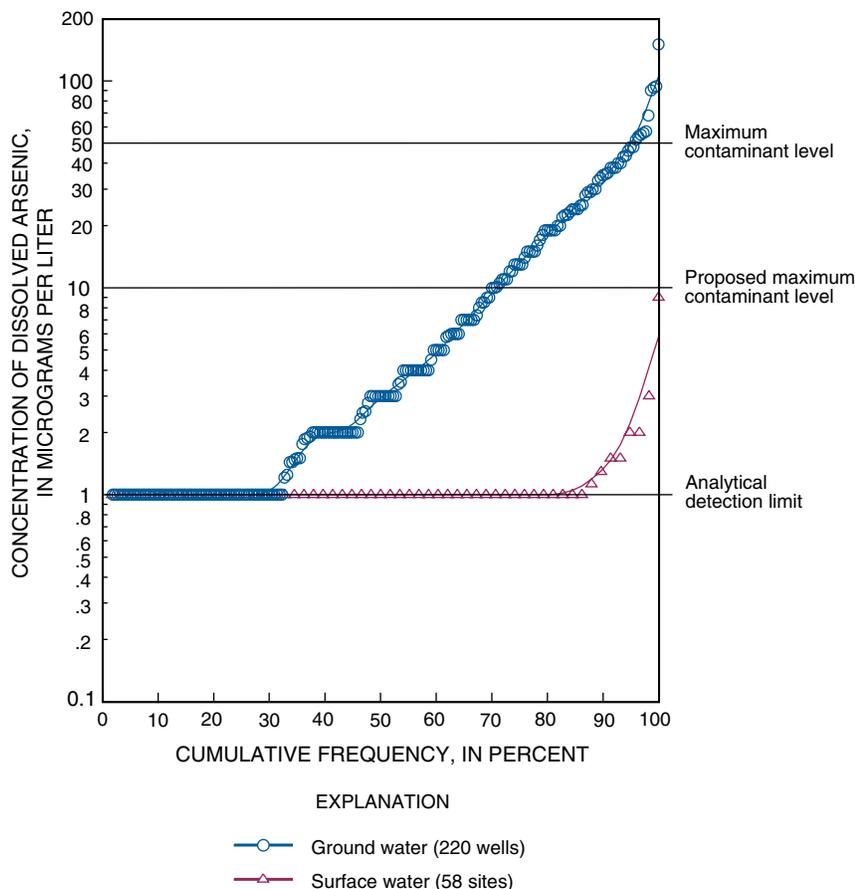


Figure 3. Dissolved-arsenic concentrations in ground- and surface-water samples from Cook Inlet Basin.

Additional Reading

Canadian Council of Ministers of the Environment, 1999, *Canadian sediment quality guidelines for the protection of aquatic life*: URL <<http://www.ec.gc.ca/ceqgrcqe/sediment.html>> (accessed June 8, 2001).

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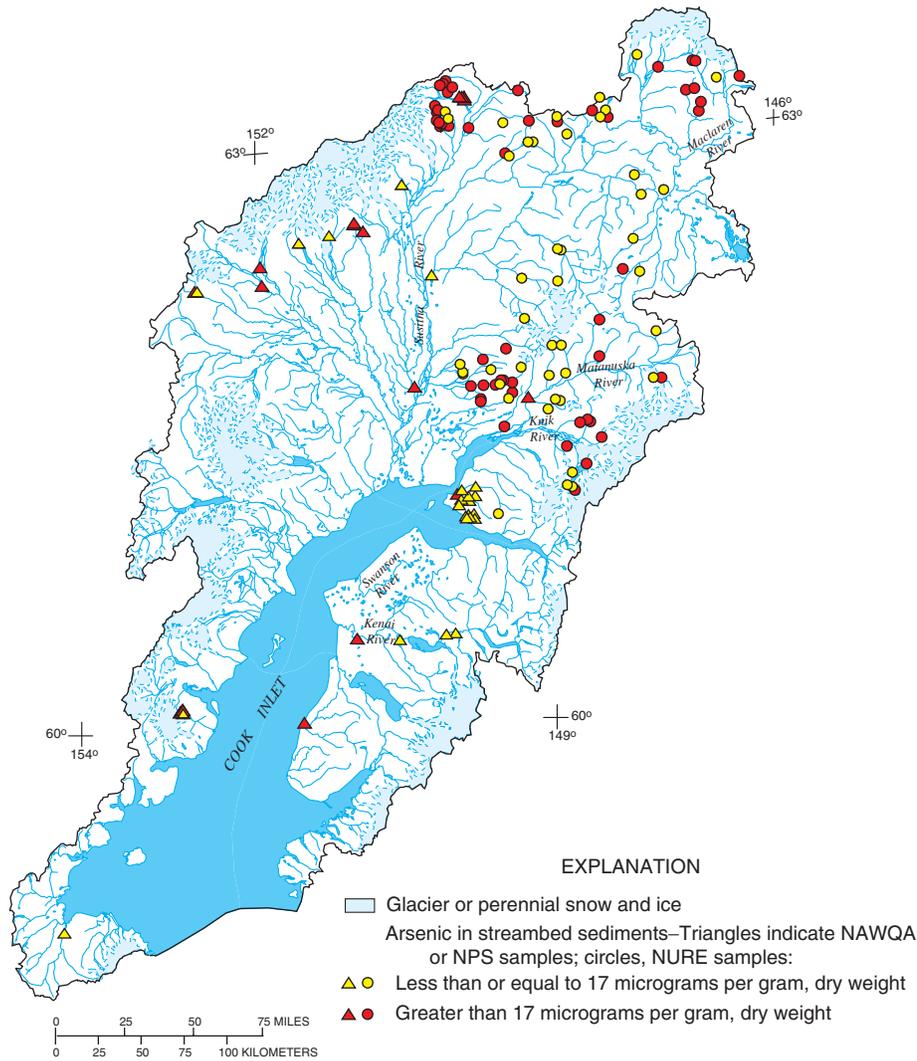


Figure 4. Concentration of arsenic in National Water-Quality Assessment (NAWQA) Program, National Park Service (NPS), and National Uranium Resource Evaluation (NURE) streambed-sediment samples



Figure 5. Hydrologist Tim Brabets sieving fine-grained streambed sediments. Photograph by Steve Frenzel, 1998.

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