OCCURRENCE AND DISTRIBUTION OF TRACE ELEMENTS IN LAKE ROOSEVELT BEACH, BED SEDIMENTS, AND AIR

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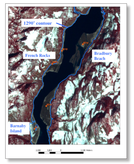
2001 BED SEDIMENT STUDY

Objective

Determine the concentrations of trace metals in the fine-grained fraction of exposed beach, bed, and bank sediments along the Columbia River from the Canadian border to the Grand Coulee Dam.

Approach

Site Selection



Target sampling sites - Six large exposed areas known to be sources for air-borne fine-grained particulate matter during high wind events.

Spatially Distributed sampling sites - Eighteen sites selected to provide a broad assessment of the distribution of trace elements in exposed beach and bed sediments.

Reference sites - Three sites located in glacial sediments above high water along Lake Roosevelt, and two upstream sites at Lower Arrow Lake in Canada.

Riverine slag sample - Site located a few kilometers downstream of the Trail, British Columbia smelter.

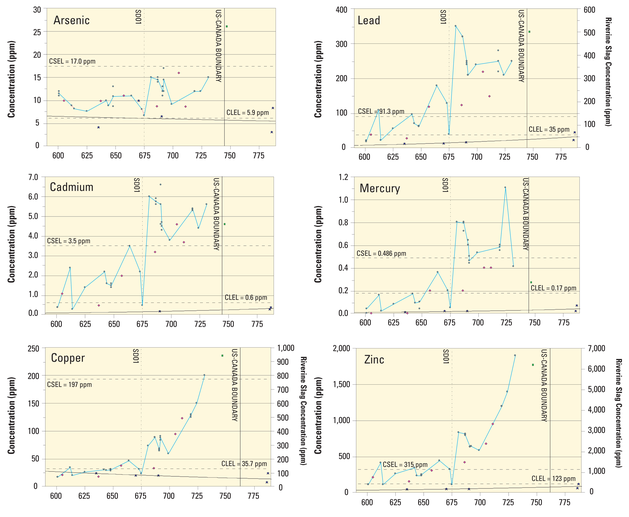
Sediment Sampling Methods

Each reservoir sample was a composite of 15 subsamples collected at each site. Each reference and riverine slag sample was comprised of material taken from only one location at each site.

Results

Samples were collected between April 23 and May 4, 2001.

Trace element concentrations in the surficial bed sediments varied, but the major slag components of arsenic, cadmium, copper, lead, and zinc showed pronounced decreasing concentration gradients from the Canadian Border to Grand Coulee Dam. Concentrations of copper, lead, and zinc exceeded the Canadian trace metal probable-effect level guidelines for adverse biological affects in aquatic systems at several sites in the upper reach of the reservoir.



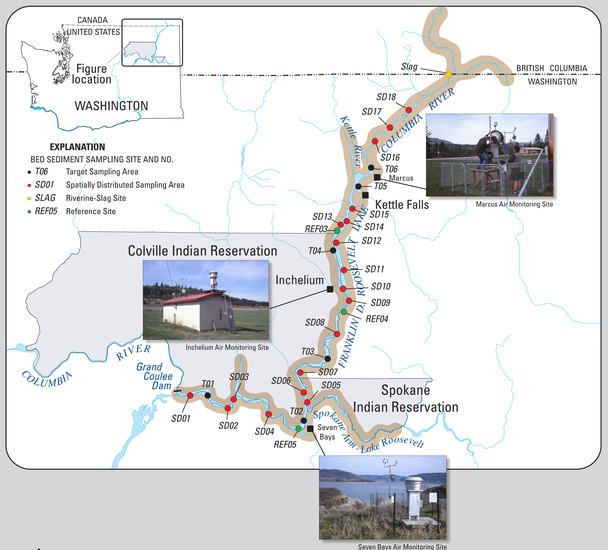
Explanation
- Spatial Site
- Reference Site
- Target Site
- Riverine Slag

Sediment-Quality Guidelines for fresh water environments developed by the Water Resources Branch of the Ontario Ministry of Environment and Energy (Persaud and others, 1991; Jaagumagi, 1993):

- **Canadian lowest-effect level (CLEL)** – Concentrations that affect sensitive species, but which can be tolerated by most benthic organisms. Most of the Target and Spatially Distributed sites, however, consistently had concentrations above the CLEL values.
- **Canadian severe-effect level (CSEL)** – The severe-effect level, represents trace element concentrations at which pronounced disturbances of the sediment-dwelling community can be expected. Trace element concentrations at or above the severe-effect level are considered detrimental to most benthic species.

Conclusions

- Trace elements associated with metallurgical waste and treated slag (arsenic, cadmium, copper, lead, and zinc) are present in the fine-grained fraction (<63 µm) of exposed bed sediments along the length of Lake Roosevelt.
- The slag related trace elements showed pronounced concentration gradients from near the International Border to Grand Coulee Dam.
- Concentrations of all slag related trace elements generally were above the Canadian Lowest-Effect Level exposure guidelines for benthic organisms. Copper, lead, and zinc concentrations, however, exceeded the Canadian Severe-Effect Level guidelines for benthic organisms at several sites, primarily those in the upper reach of the reservoir (SD16, SD17, SD18, T05, and T06).
- It is expected that the trace elements found in the exposed bed sediments during reservoir water level draw-down events will become components of the wind-blown dust resulting from the drying and entrainment into the lower atmosphere.

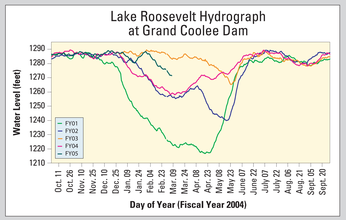


Background

A lead-zinc smelter in Trail, British Columbia, Canada, has discharged metallurgical waste, dissolved trace metals, and slag directly into the Columbia River at an average rate of about 360 metric tons per day from 1930 until the mid-1990's (Cominco Metals, 1991).

Water levels in Lake Roosevelt are lowered for flood control purposes January through April every year exposing extensive reaches of sediments contaminated with arsenic, cadmium, copper, lead, mercury, and zinc.

The exposed sediments dry, and the fine grained material can become airborne and be transported by the prevailing winds throughout the Lake Roosevelt area. Concern is growing over the potential threat of airborne contaminants to human health.



Analytical Methods

- Each sediment sample was freeze-dried and sieved to < 63 µm. A subsample was then digested using a four-acid digestion process. Analysis was done using Inductively Coupled Plasma – Atomic Emission Spectroscopy or Flame Atomic Absorption Spectroscopy (AAS) for 43 trace elements. Cold Vapor-AAS was used to analyze for mercury.
- For the air samples, each filter was weighed before and after sampling to determine the particle mass. Each filter was then digested using the four-acid digestion process. Analysis was done using Inductively Coupled Plasma – Atomic Emission Spectroscopy or Flame Atomic Absorption Spectroscopy (AAS) for 43 trace elements. Cold Vapor-AAS was used to analyze for mercury.

2002-PRESENT AIR SAMPLING STUDY

Objectives

Determine concentrations of trace elements in airborne dust during ambient and dust-event conditions
Determine if exposed beach and bed sediments are the source of the airborne trace elements

Approach

Sample during significant lake draw-down events
- Winter - January through June
- Autumn - about September

Sampling began in January 2002

Install air monitors throughout reservoir in late 2001
- Seven Bays
- Inchelium
- Kettle Falls (discontinued at end of 2002), replaced with Marcus site in January 2003

Air Sampling Methods

Take air samples during periods of significant lake level draw-down.
- Sample every 6th day during draw-down season
- Sample high wind/dust events

PM 10 High Volume Air Samplers
- 24 h samples on quartz-fiber filters every 6th day
- PM 10 sampling using EPA Method I-2.1

2004 Modifications

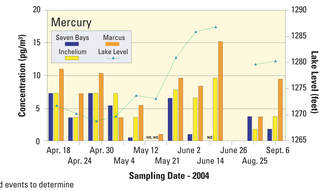
Sampling frequency changed to increase sampling events during low-water periods
- Sample every 12th day in January and February
- Sample every 6th day in March
- Sample every 3rd day in April and May

Mercury (Hg) samples were taken starting in April 2004

The Hg PM 10 concentrations were very low, in the pg/m³ range. There appears to be an increasing Hg air concentration gradient from Seven Bays to Marcus.

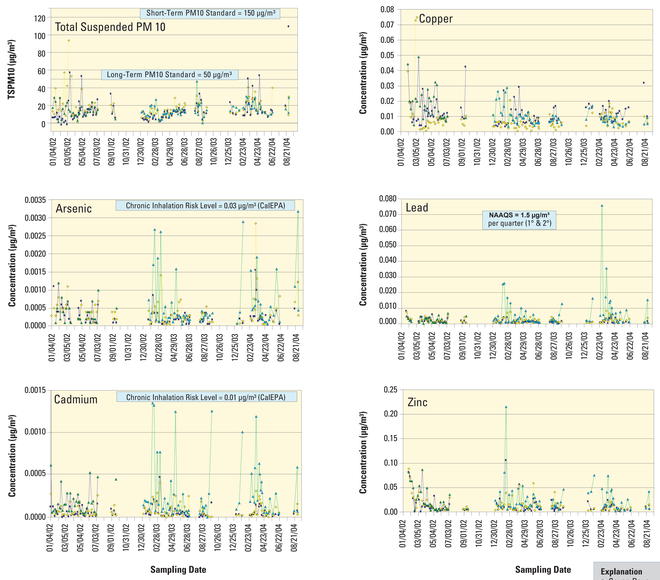
The mean Hg PM 10 concentrations at Seven Bays, Inchelium, and Marcus were 4.66, 5.93, and 7.88 pg/m³, respectively.

Total Hg background levels in the atmosphere throughout the Northern Hemisphere are in the range of 1 to 2 ng/m³.



Results

Air sampling was done at three sites on a regular schedule from January through June, and for one month in the fall. Extra samples were taken during high wind events to determine if the airborne concentrations of trace metals increase during these periods. The air samples collected particles of a mean diameter of 10 micrometer or less (PM 10). The results showed that many of the same trace metals found in the bed sediments also were present in the air at nanogram per square meter concentrations. The mean PM 10 concentrations at the sampling sites ranged from <10 µg/m³ to 50 µg/m³, and were below the current USEPA PM 10 air quality standards. Trace metal concentrations in air also were usually one or more orders of magnitude below any established air quality standard or reference level. These low levels may be due to the high water levels in recent years and the resulting minimization of exposed beach and bed sediments. In many cases, the mean 2004 concentrations were nearly two times higher than observed in 2003. The increased concentration is most likely due to the lower water levels and duration of time they were kept low (see hydrograph under Background).



Conclusions

- The PM 10 concentrations did not exceed the EPA Short- or Long Term Standards.
- Air concentrations of slag-related trace elements were low, in the sub-ng/m³. Observed concentrations were below the established chronic inhalation risk levels.
- Lake levels in 2002-04 were not as low as in 2001, but there does appear to be a correlation between lake level and airborne particle and trace metal concentrations.
- Mercury air concentrations also were low, in the pg/m³ range. These levels, however, may have ecological significance.

References Cited

Jaagumagi, R., 1993, Development of the Ontario provincial sediment quality guidelines for arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel, and zinc: Ontario Ministry of Environment and Energy, Water Resources Branch, 10 p., plus appendices.

Persaud, D., Jaagumagi, R., and Hayton, A., 1991, The provincial sediment-quality guidelines: Ontario Ministry of Environment and Energy, Water Resources Branch, 23 p.

Poster presentation at the 5th Symposium on the Hydrogeology of Washington State, April 12-14, 2005, Tacoma, Washington

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