Metals and Trace Elements in Sediment and Biological Samples from the Vicinity of the Kennecott Copper Smelter, McGill, Nevada - 1997

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Introduction

The Kennecott Mineral Company (Kennecott) Reduction Plant, which operated from 1903 to 1983, is located in the Steptoe Valley near McGill, in White Pine County, Nevada (Ecology and Environment, Inc. 1990). The site, consisting of 4,000 acres at an approximate elevation of 6,120 feet, is located on private land. The Egan Range lies to the west and the Duck Creek Range lies to the east, both areas being administered by the Bureau of Land Management (BLM). The Schell Creek Range lies further to the east and is administered by the U.S. Forest Service. Lands managed by BLM also occur to the north and south of the facility.

Kennecott originally purchased the property in 1920 and managed the facility at least up to 1990. Standard Oil purchased Kennecott from British Petroleum in 1981, Rio Tinto Zinc purchased Kennecott from Standard Oil in June 1989, and the parent company to Kennecott in 1990 was the Rio Tinto Zinc Corporation, headquartered in London, England (Ecology and Environment, Inc. 1990).

Copper ore was transported to the facility from mines near the city of Ruth, Nevada, about 15 miles to the south (Ecology and Environment, Inc. 1990). Copper ore from Utah was also smelted at the facility from 1978 to 1983. Copper ore was milled and concentrated by froth floatation. The froth containing the copper was delivered to the on-site smelter and the tailings were disposed of in the tailings pond of approximately 3,700 acres. Slag from the smelting process was also disposed in the tailings area. The older tailings in the deeper areas of the tailings pond have a higher copper concentration due to a less efficient extraction process prior to the 1950’s. The tailings are piled 10 feet high in the west and 90 feet high in the east where they had been carried by the wind (Ecology and Environment, Inc. 1990). Water was used to distribute the tailings in the pond. Water was recycled from the northwest corner of the tailings pond and reused in processing ore. Bassett Lake was constructed by Kennecott in 1942 as a surge pond for excess water from the tailings area via discharge to Tailings Creek (Ecology and Environment, Inc. 1990). During the operation of the facility, 284 million tons of ore were processed, with 95 to 97% of the ore disposed of as tailings, with the remainder smelted, with slag as a waste (Ecology and Environment, Inc. 1990). The Nevada

Department of Wildlife (NDOW) reported that a gold recovery process was also present at the site (Ecology and Environment, Inc. 1990). The mill ceased operations in 1978 and the smelter in 1983. Revegetation of the tailings area began in 1978.

Releases of contaminants from the tailings area to surface water have occurred. A flash flood in 1975 resulted in a tailings release to Tailings Creek which caused a fish kill estimated to involve 10,000 to 13,000 trout (Ecology and Environment, Inc. 1990). Surface water samples from Bassett Lake contained the following concentrations of metals: in 1985 - copper 20 µg/L, iron 150 µg/L, and zinc 10 µg/L; in 1988 - cadmium <5 µg/L, copper 10 µg/L, iron 70 µg/L, lead <5 µg/L, nickel 20 µg/L, and zinc <10 µg/L; in 1990 - chromium 50 µg/L, copper 20 µg/L, iron 90 µg/L, lead <5 µg/L, nickel 20 µg/L, and zinc 20 µg/L (Ecology and Environment, Inc. 1990).

In 1986, NDOW analyzed water, sediment, and fish from Bassett Lake (Ecology and Environment, Inc. 1990). The following results were reported for water: arsenic < 3 µg/L, copper 10 µg/L, iron 90 µg/L, mercury < 0.5 µg/L, and zinc not detected (detection limit unknown). They also found 8.6 µg/g arsenic, 2,226 µg/g copper, and < 0.25 µg/g mercury in sediment, as well as 0.04 µg/g mercury in fish. Copper tailings were said to have undoubtedly reached the lake

Wetlands occur down gradient of the area, downstream of Bassett Lake. These wetlands provide habitat for up to six species that were previously classified as species of concern by the Fish and Wildlife Service. Relict dace (*Relictus solitarius*) exist in Steptoe Slough, approximately 8 miles downstream of the site, and Mont Neva paintbrush (*Castilleja salsuginosa*) near the waterway, approximately 15 miles downstream (Ecology and Environment, Inc. 1990).

The Nevada Department of Wildlife NDOW managed a fishery at Tailings Creek and Bassett Lake, with fish stocking in the 1950's and 1970's (Ecology and Environment, Inc. 1990). NDOW managed Bassett Lake as a northern pike (*Esox lucius*) and largemouth bass (*Micropterus salmoides*) fishery, with common carp (*Cyprinus carpio*) also being present. Bassett Lake was said to be a popular fishing spot.

Atmospheric inputs to the environment have occurred in the form of fugitive dust emissions from the tailings pile. Atmospheric emissions of a variety of environmental contaminants from smelters at other sites have been documented (Beyer and Storm 1995) and likely occurred at this site. Several complaints of dust emissions from the tailings pile had been received from neighboring communities in the 1980's. Concentrations of some metals (e.g., cadmium, copper, iron, lead, manganese, selenium, and zinc) in air samples collected downwind of the tailings were higher than in background samples, indicating release of contaminants to the air (Ecology and Environment, Inc. 1990). Reports in the late 1990's indicated that attempts to revegetate the tailings pile to control dust emissions and water infiltration had not been fully successful. The predominant wind direction is said to be from south to north, but may change to a west to east direction at times (Ecology and Environment, Inc. 1990).

Based on this information, there was a high probability that Department of the Interior trust resources were exposed to trace elements at this site. Therefore, the aquatic community was sampled. Emergency analytical funds were received from the Environmental Contaminants Program of the U.S. Fish and Wildlife Service in Portland, Oregon, for the analysis of samples from the site.

Methods

The site was visited by Peter Tuttle and John Miesner on August 19-20, 1997, for reconnaissance of the area and for the collection of samples of sediment, vegetation, aquatic invertebrates, and fish. Samples were collected on August 19, 1997, using the following methods. Sediment samples were collected with a 2-inch core sampler, mixed in clean 500 ml nalgene jars, and placed in chemically-clean glass jars in the field. Vegetation was collected by hand, washed in site water, and placed in chemically-clean glass jars in the field. Aquatic invertebrates were collected with a kicknet, sorted in the field, and placed in chemically-clean glass jars in the field. Fish were collected with nets and placed in chemically-clean glass jars or clean zip-lock bags in the field. All samples were stored on ice in the field and frozen upon return to the laboratory. Data on sample locations, sample types, and sample weights are provided in Table 1. Sediment, vegetation, and aquatic invertebrate samples were composites, whereas fish samples were presumably of single individuals.

The sampling area is shown in Figure 1. Samples V01 and S07 were collected on Duck Creek, upstream of Bassett Lake. Sample H09 was collected on Tailings Creek; however, the exact site is unknown. The most likely site is the same as that for sample I03, which was collected at the northwest corner of the tailings pile, west side of tailings. Sample I04 was presumably collected on North Tailings Creek on the north side of the tailings. Samples S08, V02, H05, and H06 were collected at Bassett Lake.

Samples were submitted to the Patuxent Analytical Control Facility (PACF) of the U.S. Fish and Wildlife Service in Laurel, Maryland, for analysis of metals and trace elements. PACF was responsible for quality assurance and quality control for the analyses.

Results and Discussion

Field Observations

The following data were collected in the field: Tailings Creek, northwest corner of tailings pile, August 19, 1997 - pH 7.4, specific conductivity 830 µS/cm, salinity 0.52 parts per thousand, flow estimated at 3-5 cubic feet per second, water clear, abundant aquatic and emergent vegetation of several species, abundant aquatic invertebrates of several species, common carp common in creek, dace abundant north of confluence, large trout present below confluence, frogs noted; Bassett Lake, August 19, 1997 - outflow temperature 21ºC, pH 8.5, specific conductivity 1050 µS/cm, abundant aquatic/emergent vegetation and fish noted in the water of the lake; Tailings Creek, north fork, August 20, 1997 - pH 7.8, specific conductivity 450 µS/cm; Tailings Creek below confluence, August 20, 1997 - pH 7.6, specific conductivity 900 µS/cm.

Analytical Results

Small numbers of samples were collected; therefore, comparisons between samples should be viewed with caution. Concentrations of elements in sediment were generally much higher in the sample from Bassett Lake than in the sample from Duck Creek, but with the following exceptions: aluminum, arsenic, boron, barium, magnesium, and strontium. Comparisons between sites for vegetation and aquatic invertebrates are complicated by the collection of different types between sites. However, copper, mercury, and molybdenum concentrations were much higher in pondweed from Bassett Lake than in bryophytes from Duck Creek by factors of about 21, 15, and 10 times. Aquatic invertebrates were only collected from the two tailings creeks, with amphipods from the North Tailing Creek tending to have somewhat higher concentrations of elements, except for beryllium, chromium, copper, nickel, lead, strontium, and vanadium. Fish were collected from Bassett Lake and Tailings Creek, with comparisons between sites being possible for common carp and comparisons between species (i.e., northern pike vs. common carp) being possible for Bassett Lake. Concentrations of elements in common carp were generally similar between sites. Common carp from Bassett Lake had considerably higher concentrations of aluminum, copper, iron, strontium, and zinc than northern pike from the same site. These latter differences could be due to differences in fish size and/or feeding habits for the two species.

Interpretation of Sediment Data

Concentrations of selected elements in sediments were compared to consensus-based sediment quality guidelines for freshwater ecosystems provided by MacDonald et al. (2000). Arsenic concentrations were well below the threshold effect concentration (TEC; i.e., 9.79 µg/g dry weight). The cadmium concentration in the sample from Bassett Lake exceeded the TEC (i.e., 0.99 µg/g dry weight) but was the below the probable effect concentration (PEC; i.e., 4.98 µg/g dry weight). Chromium concentrations from both sites were well below the TEC (i.e., 43.4 µg/g dry weight). The copper concentration from Bassett Lake far exceeded the PEC (i.e., 149 µg/g dry weight), whereas the concentration in the sample from Duck Creek was well below the TEC (i.e., 31.6 µg/g dry weight). The copper concentration found in the earlier sample collected by NDOW (see Introduction above) was even higher than that in our sample. The mercury concentration in the sample from Duck Creek approached the TEC (i.e., 0.18 µg/g dry weight), whereas the sample from Bassett Lake exceeded the TEC, but was below the PEC (i.e., 1.06 µg/g dry weight). Nickel concentrations were well below the TEC (i.e., 22.7 µg/g dry weight). Lead concentrations were also well below the TEC (i.e., 35.8 µg/g dry weight). The zinc concentration in the sample from Bassett Lake approached the TEC (i.e., 121 µg/g dry weight). The iron concentration in the sediment sample from Bassett Lake exceeded the concern level for iron in sediment of 21,200 µg/g dry weight identified by Persaud et al (1993). The manganese concentration in this sample also exceeded the concern level (i.e., 460 µg/g dry weight) identified by Persaud et al. (1993). Selenium concentrations in sediment were far below the toxicity threshold (i.e., $\geq$ 4 µg/g dry weight) identified by Lemly and Smith (1987). The combined effects of multiple elements might increase the likelihood of toxicity to aquatic biota.

Interpretation of Biological Data

Pondweed, aquatic invertebrates, and fish were considered as potential food sources to migratory birds. Therefore, concentrations of elements in them were evaluated in relation to dietary effect concentrations. In evaluating the concentrations found in this study, one should consider the total diet being consumed in determining effects, not just a single dietary type. It is unknown if bryophytes are consumed by wildlife in this area; therefore, residues in that sample were not evaluated. Dietary effects concentrations for barium, beryllium, iron, magnesium, manganese, and strontium are not known; therefore, these elements are not discussed further.

- An aluminum concentration of 5,000 µg/g dry weight was considered an adverse dietary effect level in waterfowl (Sparling 1990). Aluminum concentrations in samples from this study were far below this level.
- An arsenic concentration of 30 µg/g dry weight in the diet of mallard (*Anas platyrhynchos*) ducklings was associated with reduced weight gain (Camardese et al. 1990). Arsenic concentrations in this study were much lower.
- Weight gain of mallard ducklings whose parents received a diet containing 30 µg/g dry weight of boron and the reproductive success of adult mallards that received a diet containing 1,000 µg/g dry weight were significantly reduced (Smith and Anders 1989). The boron concentration in the pondweed sample from Bassett Lake exceeded the former concentration.
- Cadmium concentrations were far below a level of concern in mallard ducklings of 20 µg/g dry weight (Cain et al. 1983).
- Eisler (2000a) indicated that one might expect potential adverse effects on health and reproduction of wildlife when chromium in the diet exceeds 10 µg/g dry weight. Chromium concentrations in both samples of aquatic invertebrates exceeded this level by more than 20 times, whereas concentrations in other samples were much lower than the threshold.
- Eisler (2000a) considered poultry diets containing < 200 µg/g dry weight of copper to be safe. Copper concentrations in this study did not exceed this level.
- Adverse reproductive effects in mallards were associated with a dietary concentration of 0.5 µg/g dry weight of mercury (Heinz 1979). The mercury concentration in pondweed from Bassett Lake exceeded this level, whereas the concentration in amphipods from North Tailings Creek approached it. We find the elevated mercury level in the pondweed sample to be unusual as plants are not expected to take up significant amounts of mercury. The elevated level might be due, in part, to attached sediment on the sample (mercury concentrations in sediment and pondweed were similar). The sediment, if present, on the pondweed would also be ingested if the pondweed was consumed by a bird.
- Growth reduction in birds was associated with dietary concentrations of molybdenum of 200 to 300 µg/g dry weight (Eisler 2000b). Molybdenum concentrations in this study were far lower.
- A dietary concentration of 800 µg/g fresh weight of nickel has been associated with adverse effects to adult mallards (Eisler 2000a). All nickel concentrations in this study were far lower.
- An avian dietary concentration of < 5 µg/g dry weight of lead was proposed to be protective by Eisler (2000a). All lead concentrations in this study were lower than this threshold.
- The lower threshold of dietary selenium exposure associated with adverse reproductive effects in birds is 3 µg/g dry weight (U.S. Department of the Interior 1998). Selenium concentrations in this study did not exceed this threshold.
- The avian dietary concern level for vanadium is 100 µg/g dry weight (White and Dieter 1978). Vanadium concentrations were far lower in this study.

- The dietary effect levels for zinc proposed for the protection of birds are < 178 µg/g dry weight to prevent marginal sublethal effects and < 2000 µg/g dry weight to prevent the death of chicks and ducklings (Eisler 2000a). The zinc concentrations in both common carp samples from this study exceeded the threshold for sublethal effects, but not the level to prevent death.

Schmitt and Brumbaugh (1990) reported geometric mean, 85th percentile, and maximum concentrations (wet weight basis) of arsenic, cadmium, copper, mercury, lead, selenium, and zinc in freshwater fish from a United States national monitoring program conducted in 1984. These data are used here as a general benchmark for residue concentrations in fish.

- Arsenic concentrations in this study were well below the 85th percentile (i.e., 0.27 µg/g).
- Cadmium concentrations in this study were slightly below the 85th percentile (i.e., 0.05 µg/g).
- The 85th percentile (i.e., 1.0 µg/g) for copper was approached by the concentration in the northern pike sample (i.e., 0.987 µg/g) and exceeded by the concentrations in the common carp samples from Bassett Lake and Tailings Creek (i.e. 1.95 and 4.63 µg/g), respectively).
- Mercury concentrations in this study were below the 85th percentile (i.e., 0.10 µg/g).
- Lead concentrations in this study were below the 85th percentile (i.e., 0.22 µg/g).
- The selenium concentration in the northern pike sample from this study (i.e., 0.505 µg/g) was slightly above the 85th percentile (i.e., 0.42 µg/g), whereas the concentrations in common carp were lower.
- The 85th percentile for zinc (i.e., 34.2 µg/g) was exceeded in both common carp samples (i.e., 107 µg/g for Bassett Lake and 68.4 µg/g for Tailings Creek), whereas the northern pike sample had a somewhat lower concentration (i.e., 29.4 µg/g).

Jarvinen and Ankley (1999) compiled a database linking effects of various contaminants to tissue residues in a variety of aquatic organisms from controlled studies. The length and route of exposure in the studies cited likely affected test results, whereas tissue residues may have been secondary. Cadmium concentrations associated with reduced survival of the freshwater amphipod *Hyalella azteca* were at least an order of magnitude higher than those found in our study. Concentrations of arsenic, cadmium, chromium, lead, mercury, nickel, selenium, and vanadium in whole bodies of fish from this study were lower than those associated with adverse affects on survival, growth, and/or reproduction in moderate to long-term studies that were cited by Jarvinen and Ankley (1999). No moderate or long-term studies where whole bodies of fish were analyzed for copper were found in the data base. Adverse effects on growth and survival were found in embryo to adult freshwater flagfish (*Jordanella floridae*) that were exposed to 51 to 139 µg/L zinc sulfate for 100 days; the fish had whole body zinc concentrations of 40 to 68 µg/g (wet weight) zinc. These zinc concentrations were similar to or lower than zinc concentrations found in common carp from our study. The zinc concentrations in the common carp appear to be elevated in relation to these data, especially when viewed in relation to the data from Schmitt and Brumbaugh (1990), and are of potential concern. Zinc exposure from water alone in these studies appears to be higher than those reported at the site (see Introduction above), but fish at the site were also exposed through the diet.

Summary and Recommendations

Two samples each of sediment, vegetation, and aquatic invertebrates, and three samples of fish were collected from the vicinity of the site of the McGill copper smelter in White Pine County, Nevada in August 1997. Concentrations of cadmium iron, mercury, manganese, and zinc in sediment samples from Bassett Lake, downstream of tailings on the smelter site, closely approached or exceeded threshold effect concentrations for aquatic ecosystems, whereas the concentration of copper greatly exceeded the probable effect concentration. Concentrations of boron, mercury, and zinc in biological samples from Bassett Lake exceeded threshold concentrations for adverse dietary effects to migratory birds or wildlife, whereas concentrations of chromium in aquatic invertebrates from creeks adjacent to tailings greatly exceeded the potential dietary effect level. The zinc concentrations in common carp from Bassett Lake and Tailings Creek were of concern.

Although this sampling was very limited, additional sampling and study of the area seems justified in order to better determine if metals and trace elements from the site are adversely impacting Fish and Wildlife Service trust resources. Future sampling, if conducted, should include the collection of samples downstream of Bassett Lake as well as samples from predominantly downwind areas where aerial fallout from smelter stacks and fugitive dust could be expected.

Elevated concentrations of uranium and associated radio nuclides have recently been found at the abandoned copper mine near Yerington, Nevada, which were associated with waste fluids involved in the recovery of copper (www.nv.blm.gov/carson/Planning_Env_Coord/Yerington/BLMhasp4Aug17meetFinalRev.pdf). The potential for similar problems at the McGill site is unknown; however, appropriate future sampling should be strongly considered.

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Table 1. Collection data for sediment, vegetation, aquatic invertebrates, and fish samples collected near the copper smelter at McGill, Nevada, August 1997. Coordinates were approximated.

Sample No.	Type	Location	Latitude	Longitude	Weight (g)
S07	Sediment	Duck Creek	39º 28'	114º 50'	189.3
S08	Sediment	Bassett Lake	39º 28'	114º 52'	141.7
V01	Bryophytes	Duck Creek	39º 28'	114º 50'	97.4
V02	Pondweed	Bassett Lake	39º 28'	114º 52'	130.4
I03	Hemipterans	Tailings Creek[1]	39º 28'	114º 50'	15.1
I04	Amphipods	N. Tailings Creek[2]	39º 28'	114º 50'	10.1
H05	Pike	Bassett Lake	39º 28'	114º 52'	246.6
H06	Carp	Bassett Lake	39º 28'	114º 52'	979.6
H09	Carp	Tailings Creek	39º 25'	114º 50'	1630.3

[1] Northwest corner of tailings pile, west side of tailings.
[2] North side of tailings.

Table 2. Concentrations (µg/g dry weight) of metals and trace elements and percent moisture in sediment, vegetation, aquatic invertebrates, and fish from sites near the copper smelter at McGill, Nevada, August 1997.

Sample Type	Location	Al	As	B	Ba	Be	Cd	Cr	Cu	Fe	Hg
Sediment	Duck Creek	7915.	5.03	16.8	135.	0.33	0.44	4.41	19.5	8666.	0.144
Sediment	Bassett Lake	6760.	3.32	22.0	53.7	0.31	1.67	16.1	997.	24856.	0.672
Bryophytes	Duck Creek	3607.	2.80	71.8	154.	0.16	<0.11	2.20	8.41	3606.	<0.048
Pondweed	Bassett Lake	1700.	1.93	105.	118.	<0.24	<0.24	2.82	182.	3084.	0.732
Hemipterans	Tailings Creek	375.	2.55	7.04	69.0	<0.28	<0.26	238.	52.2	2107.	<0.216
Amphipods	N. Tailings Cr.	772.	5.24	16.7	347.	<0.40	3.60	225.	62.6	3069.	0.459
Pike	Bassett Lake	<4.46	<0.44	2.52	6.48	<0.11	0.22	<0.56	4.54	57.3	0.130
Carp	Bassett Lake	46.2	<0.55	<2.7	3.53	<0.14	0.23	<0.69	10.8	223.	0.215
Carp	Tailings Creek	33.9	<0.27	2.51	2.34	<0.08	0.17	0.547	16.5	170.	<0.071

Sample Type	Location	Mg	Mn	Mo	Ni	Pb	Se	Sr	V	Zn	Percent Moisture
Sediment	Duck Creek	28932.	325.	<1.61	3.87	5.60	<0.14	74.7	6.94	28.9	42.1
Sediment	Bassett Lake	7371.	633.	19.5	7.56	9.51	0.792	84.0	27.6	117.	52.4
Bryophytes	Duck Creek	7550.	410.	3.72	<2.28	4.89	<0.21	115.	3.52	14.3	59.3
Pondweed	Bassett Lake	9141.	680.	36.6	<4.73	<4.73	0.868	328.	3.41	52.4	82.2
Hemipterans	Tailings Creek	3487.	1362.	6.02	86.2	<1.39	1.23	344.	<1.39	36.5	91.0
Amphipods	N. Tailings Cr.	4316.	1767.	18.6	82.8	<2.02	1.88	335.	<2.02	59.4	91.7
Pike	Bassett Lake	1551.	12.8	<2.23	<0.56	<0.56	2.32	27.2	<0.56	135.	78.3
Carp	Bassett Lake	1886.	13.4	<2.75	<0.69	<0.69	2.02	50.1	<0.69	591.	81.9
Carp	Tailings Creek	1093.	21.7	<1.64	<0.41	<0.41	1.15	30.2	<0.41	244.	72.0

Figure 1. Map showing the vicinity of the copper smelter at Mc Gill, Nevada, adjacent tailings, and downstream areas where samples of sediment, vegetation, aquatic invertebrates, and fish were collected for metal and trace element analyses in August 1997. From U.S. Geological Survey, McGill, Nevada 15’ quadrangle.