

## 1.0 INTRODUCTION

Several historical mine sites in the Juneau, Alaska, area have recently been evaluated by the Alaska Department of Environmental Conservation (ADEC) and the United States Environmental Protection Agency (EPA). These investigations have included sites owned by the City and Borough of Juneau (CBJ) and Alaska Electric Light and Power Company (AEL&P). The results of sampling in Silver Bow Basin have indicated that heavy metals may be present in concentrations above background levels in the area of the Perseverance mill and Ebner Falls (Tryck, Nyman, and Hayes, 1987). Because the CBJ and AEL&P are concerned about the possibility of the suspected contamination causing environmental impairment, Versar was authorized to conduct an investigation of the Silver Bow Basin, the tailings deposited at and near tidewater along Douglas Island, the Alaska Juneau Mine (AJ) rock dump, and the Treadwell cyanide mill and tailing sites. The goal of the investigation was to determine if metals are present in high enough concentrations to raise concerns about environmental impairment, and to determine if special management practices are necessary. *SI*

## 2.0 ENVIRONMENTAL SETTING

### 2.1 Site Location and Demographics

The sites to be investigated are in or near the City of Juneau, Alaska. Access to Juneau is by boat or airplane. The population of Juneau is approximately 27,000. The locations of the study areas are shown in Figure 2-1.

The Perseverance site and Ebner Falls are located in Silver Bow Basin, an undeveloped recreational area approximately two miles east of downtown Juneau. Steep, forested mountains surround the basin and the Juneau Ice Field covers the top of the mountains to the east. Gold

Creek flows to the west through the center of the basin and discharges over Ebner Falls, a narrow gap at the western end of the basin, to Last Chance Basin. The Perseverance Mine is near the east end of the basin. The only developed access is a hiking trail, which originates in Last Chance Basin west of Silver Bow Basin. The Alaska Juneau glory hole, a large open pit mine, is located to the west of the Perseverance mill site. The Webster mill site is located approximately 500 feet upstream from Ebner Falls.

The AJ rock dump begins one-half mile southeast of downtown Juneau and extends 2,800 feet to the southeast at tidewater in Gastineau Channel. The rock dump includes both unprocessed waste rock from the mine, and tailings from the gold extraction process. The only structures on the rock dump are communications satellite dishes, a Union Oil tank farm located on the northwest end of the rock dump, and the Juneau wastewater treatment plant located at the southeast end. Because the mountains border the channel so closely, the area adjacent to the rock dump has not been developed.

The tailings located along Gastineau Channel on Douglas Island, are from the operations of the Treadwell Group mines. The Sandy Beach area, on the northwest end of the tailings, has been developed as a recreational area and includes softball fields, a soccer field, tennis courts, and a picnic area. Residences are located to the west, uphill from Sandy Beach. Tailings from the Treadwell Group mining operations extend virtually continuously in a southeast direction from Sandy Beach to the Ready Bullion Mine, a distance of approximately 8,000 feet. Included in this area are the Treadwell cyanide mill tailings, which were deposited at tidewater approximately 4,000 feet southeast of Sandy Beach at tidewater, and also at the mill site, which is 500 feet inland from the channel. Most of the tailings on Douglas Island are located

#### 5.4 Alaska Juneau Mine Dump

##### 5.4.1 Background

The AJ rock dump contains both gangue, or waste rock, and mill tailings from the AJ mill. Samples were collected from the northwest and southeast ends of the dump (see Figure 5-4). Although the work plan called for a sample from the middle of the dump, the rock in the dump appeared to be so homogeneous that a third sample did not appear to be warranted. Structures located on the rock dump include satellite communications antennas, a Union Oil tank farm at the northwest end of the dump, and the Juneau municipal wastewater treatment plant at the southeast end.

##### 5.4.2 Rock Dump Samples

The gangue is found primarily at the western end of the dump and is composed of sand, gravel, cobbles, and boulders ranging up to 24 inches in diameter (see Photo 9, Appendix A). The principal components are rock fragments of gabbro, metagabbro, and slate. The eastern end of the dump contains a greater percentage of mill tailings, which are finer (predominantly sand) and are composed of gabbro, metagabbro, slate, and individual grains of quartz, feldspar, and pyroxene. The sample from the southeast end was taken from a 10-foot high cut which exposed a number of layers (see Photo 10, Appendix A). The sample consists of a composite of the layers exposed.

## 6.0 RESULTS

The laboratory reports of the chemical analyses are included in Appendix C for the tailings, soil, and sediment samples, Appendix D for the water samples, and Appendix E for the EPTT.

Table 6-1. Results of Analyses of TAILINGS, SOIL, and Stream Sediment Samples

Sample No.	Lead	Zinc	Arsenic	Mercury	Cyanide
Soil Samples					
Perseverance Mine Area					
P1	2,440	505	1,670	17	NA <sup>1</sup>
P2	8,880	408	2,240	25	NA
P3	924	340	576	13	NA
P4	1,470	136	166	8.2	NA
P5	1,560	95	188	0.14	NA
P6	1,310	105	102	1.4	NA
P7	12,500	197	404	33	NA
P8	700	379	34	2.2	NA
P9	293	107	40	4.0	NA
P10	72	108	21	0.45	NA
P11	749	122	394	11	NA
Douglas Tailings Area					
DT1	8.6	49	4.5	0.33	<0.53
DT2	316	649	191	57	19.9
DT3	60	38	64	0.22	<0.79
DT4	511	147	350	10	49.1
DT5	119	84	75	1.1	1.28
DT6	13	34	<3.8	0.36	<0.59
Aleksa Juneau Rock Dump					
AJ1	86	232	44	<0.11	NA
AJ2	163	444	36	<0.11	
Sediment Samples					
Perseverance Mine Area					
PS1	13	92	23	<0.12	NA
PS2	14	124	33	<0.13	NA
Upper Ebner Falls					
PS3	40	96	30	<0.13	NA
PS4	24	117	27	0.26	NA

<sup>1</sup> Not analyzed for this parameter

zinc, 191 mg/kg and 350 mg/kg of arsenic, 57 mg/kg and 10 mg/kg of mercury, and 19.9 mg/kg and 49.1 mg/kg of cyanide, respectively. A soil sample collected on the hillside between the two tailings piles contains 60 mg/kg of lead, 38 mg/kg of zinc, 64 mg/kg of arsenic, 0.22 mg/kg of mercury, and cyanide was nondetectable at a reporting limit of 0.79 mg/kg. The final soil sample, taken on the beach northwest of the lower tailings pile, has 119 mg/kg of lead, 84 mg/kg of zinc, 75 mg/kg of arsenic, 1.1 mg/kg of mercury, and 1.28 mg/kg of cyanide.

One sample from the upper tailings pile was submitted for the EPIT. None of the metals exceeded the allowable concentration in the leachate (see Table 6-2).

One water sample was collected from a stream which flows over the upper tailings pile. The sample, which was collected 60 feet downslope from the tailings pile, contains 0.017 mg/l of lead, 0.199 mg/l of zinc, and 0.00036 mg/l of mercury. Arsenic and cyanide were not detected at the reporting limit of 0.01 mg/l (see Table 6-3). The pH of the water was 6.71 above the upper tailings pile and the conductivity was 650 ms. Immediately below the tailings pile, the pH was 2.67 and the conductivity was 3,400 ms. At the location where the water sample was taken, the pH was 2.8 and the conductivity was 1740 ms. Near the beach, the stream water had a pH of 2.8, and a conductivity of 1390 ms.

### 6.3 Alaska Juneau Rock Dump

Two samples were submitted for analyses from the Alaska Juneau rock dump. The metal concentrations of sample AJ1, from the northwest end of the dump, and AJ3, from the southeast end of the dump, were 86 mg/kg and 163 mg/kg of lead, 232 mg/kg and 444 mg/kg of zinc, and 44 and 36 mg/kg of arsenic, respectively (see Table 6-1). Mercury was not detected at a reporting limit of 0.11 mg/kg.

## DISCUSSION

### 7.0 Mobility of Lead, Zinc, Arsenic, Mercury, and Cyanide

#### 7.1 Mobility of Lead

The solubility of naturally occurring lead minerals is low. However, once lead is in solution, the sorption process is more efficient at scavenging lead than is precipitation (Hem, 1976). The sorption process is enhanced by the presence of naturally occurring organic materials such as humic and fulvic acids which, in general, increases the sorptive affinity of lead for clays (Guy and Chakrabarti, 1976). Low pH solutions will tend to cause a slight increase in the solubility of lead compounds, although the organic complexes are not affected by low pH to the same extent as inorganic compounds. The low pH within the tailings would tend to slightly increase the solubility of the organic lead compounds. However, the organic matter in the soil would promote the sorption of the lead on clay particles, thereby increasing the mobility of lead.

Zinc is one of the more soluble base metals. Once in solution, precipitation is effective in controlling the mobility of zinc only in highly reducing solutions (Holmes et al., 1974). Under oxidizing conditions, precipitation is only important where high concentrations of zinc are found. Zinc will form complexes with inorganic ligands and organic acids which are stable at low pH. This may effect their removal from the aquatic environment through the formation of colloids (Long and Angino, 1977). Coprecipitation with or adsorption on hydrous iron oxides also removes zinc from the aqueous environment. In the tailings, conditions do not favor precipitation of zinc in solution. However, the mobility of zinc can be reduced by the formation of colloids at the low pH in the tailings, and through adsorption by organic material and clay in the soil.

Because arsenic tends to form relatively soluble compounds and has multiple oxidation states, its geochemistry is intricate. Arsenic is

extremely mobile in the aquatic environment and cycles through the water and sediments. Waslenchuk and Windom (1978) found that arsenic complexed with organic matter was difficult to precipitate. However, Waslenchuk (1979) later demonstrated that once arsenic becomes associated with particulates, it remains bound and tends to accumulate with sediments and soils. Arsenic also tends to coprecipitate with or adsorb on hydrous iron oxides (La Pientre, 1954). Coprecipitation and adsorption are the most important methods of removing arsenic from solution in aerobic, acidic, fresh water (Gupta and Chen, 1978). The concentration of arsenic solution does not appear to be high enough to permit precipitation. However, the iron content may be high enough, particularly in the iron sulfide rich tailings pile on Douglas Island, to permit coprecipitation with iron oxides in the soil as the pH increases. Adsorption may be effective in removing arsenic from solution in soils with high clay content.

Mercury has a low solubility and shows a strong affinity for adsorption onto particulates. In aqueous systems, this is followed by settling to the bed sediments. The overwhelming majority of any dissolved mercury is removed in this manner within a relatively short time, generally near the source (Loring, 1975). The sorption of mercury is increased by the presence of organics, and is greater on clays than on sand (Reimers and Krenkel, 1974). The mercury associated with the tailings appears to behave as predicted by its low solubility and strong affinity for adsorption.

The cyanide ion can react with many metals to form compounds which are insoluble. However, if the cyanide ion is present in excess, soluble metalloccyanide complexes can be formed which can be transported in solution. In natural waters at a pH of less than 7, greater than 99 per cent of the free cyanide is present as hydrogen cyanide (Towill et al., 1978). Hydrogen cyanide has been shown to volatilize very quickly, with half of the free cyanide being lost to the atmosphere in as little

tailings and cyanide (Raef et al., 1977). Although cyanide is relatively mobile in soil, cyanide mobility is at a minimum in soils with low pH, a high percentage of clay, and high levels of iron oxides (Alesii and Fuller, 1976). It is probable that only a negligible amount of free cyanide is present in the tailings or water. In addition to the volatility of free cyanide and the low concentration of total organic cyanide, the low pH, the amount of clay in the soil, and the iron oxides present as a result of the weathering of the iron sulfides will all act to reduce the mobility of cyanide in and near the tailings.

### 7.2 Perseverance Area

The results of the analyses of the soil, sediment, and stream water samples were in general agreement with the results of the earlier studies. The concentration of the metals in the tailings disposal area is highly variable, although the lead content appears to increase towards the west side. Positive correlations of the relative concentrations of the metals exist only between lead and mercury (correlation coefficient of  $r=0.89$ ), and between zinc and arsenic (correlation coefficient of  $r=0.74$ ). The metal content of the samples does not appear to vary with the thickness of the tailings. For example, samples P6 and P7, taken from the thickest part of the tailings on the inner slope of the berm, have lead concentrations of 12,500 and 1,310 mg/kg, respectively. Sample P2, taken from the center of the tailings area, where the tailings layer is thinnest, has a lead concentration of 8,880 mg/kg. The milling and tailings disposal activities have contaminated the soil between the two operational areas, but the contamination does not appear to have affected the vegetation outside the tailings disposal area proper. It would appear that the inhibiting factor is the low pH in the tailings disposal area, rather than the metal content of the soil.

detectable amounts of mercury at a reporting limit of 0.002 mg/l. It is therefore likely that the mercury in the beach tailings is present in an immobile form. If the constant weathering to which the tailings are exposed has not removed the mercury, it is unlikely that the mercury will be released in large enough quantities to impact the environment.

It is also likely that the cyanide is present in an immobile form. Free cyanide is volatile in natural waters, particularly in water with a low pH. Over 65 years have passed since cyanide was used at the site, and free cyanide would have long since volatilized or formed a stable metal complex. Therefore, the residual cyanide appears to be present as insoluble metal compounds. The abundance of clay and the low pH in the soil surrounding the tailings pile are also conditions which favor less mobile cyanide compounds.

#### 7.4 Alaska Juneau Rock Dump

The results of the analyses of the samples from the rock dump show that metals are present in concentrations which are moderately above background levels. However, the rocks have a very similar mineralogy to the tailings in the Thane area which were mined from the same ore body. The EPTT on the Thane tailings show that no metals are present in the leachate above the acceptable levels. There is no reason to expect that the Alaska Juneau rock dump poses any greater threat than the Thane tailings.

### 8.0 CONCLUSIONS

#### 8.1 Mobility of Metals and Cyanide

The metals and cyanide appear to be relatively immobile. Because of the length of time since the tailings were deposited, it is probable that all of the easily soluble or volatile species present have been removed from the system. The remaining species are either relatively insoluble compounds or are tightly bound in the soil and sediments.

Therefore, any environmental impact of the metals and cyanide will occur at the location in which they are deposited.

#### 8.2 Perseverance Mine Area

Although metals from the mining and milling operations can be detected in the entire area between the mill and the tailings disposal area, a noticeable environmental impact can be seen only in the tailings disposal area. The level of contamination appears to drop off rapidly to the west of the tailings disposal site, and the results of the chemical analyses show that Gold Creek has not been impacted by the presence of the tailings. Although lead was found to marginally exceed the limit for the EPTT, there is no evidence, with the exception of the lack of vegetation in the tailings disposal area, that any environmental impairment has occurred. The greatest concern is that hikers could be adversely affected by contact with the metals in the tailings disposal area. *A*

There are three management alternatives for the wastes: monitor the wastes to ensure that changing conditions do not create environmental hazards; cap the wastes; or remove the wastes. The monitoring program would consist of an evaluation of the results of the regular sampling and analysis of the municipal water supply conducted by the CBJ, semi-annual analysis of water samples collected downstream from the tailings disposal area, and maintenance of the sign at the site which warns of potential hazards as a result of the presence of the tailings. The main advantage of this method is the low cost. The main disadvantage is that it permits contact with the tailings if hikers choose to ignore the sign. Capping the wastes would consist of covering the tailings with an soil or talus from the area around the site. In addition, an impermeable, synthetic liner could be laid over the tailings underneath the natural cover. The advantages of this alternative are that it limits contact with the tailings and decreases the infiltration of storm water which

hazardous waste. Although the tailings on Sandy Beach have trace amounts of mercury, the results of the EPTT demonstrate that the mercury is tightly bound to the beach sediments.

The data suggest that all of the metals and the cyanide in the tailings and soil at the Treadwell cyanide mill are relatively immobile. Therefore, the Treadwell cyanide mill tailings do not appear to pose a threat to the environment. No further action is recommended for the Douglas tailings.

#### 8.5 Alaska Juneau Rock Dump

No material has been identified as hazardous waste at this site. No further action is recommended for the rock dump.

#### 9.0 RECOMMENDATION

To reduce the risk of environmental impairment at the sites examined, the CBJ and AEL&P should address the following recommendation.

- 88-11-1: A monitoring program consisting of evaluations of the results of the regular sampling and analysis of the municipal water supply conducted by the CBJ, semi-annual analysis of water samples collected downstream from the tailings disposal area, and maintenance of the sign at the site warning of potential hazards as a result of the presence of the tailings should be implemented immediately. The monitoring program should be formalized with written procedures. Written results of each monitoring episode should be maintained. The monitoring program should include an examination of the results of the analyses for indications that mercury is being released from the Ebner Falls site.

#### 10.0 APPENDICES

Appendices A through E comprise the technical appendix to this report. The contents of the appendix are listed below.

- Appendix A. Site Visit Photographs
- Appendix B. Chain of Custody Forms