PUBLIC HEALTH ASSESSMENT

Klondyke Mine Tailings

Klondyke, Graham County, AZ

CERCLIS NO. AZ0000309294

Arizona Department of Health Services
under cooperative agreement with the
Agency for Toxic Substances and Disease Registry

The ATSDR Health Assessment: A Note of Explanation

Section 104 (i)(6)(F) of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, states "....the term health assessment" shall include preliminary assessments of potential risks to human health posed by individual sites and facilities, based upon such factors as the nature and extent of contamination, the existence of potential pathways of human exposure including ground or surface water contamination, air emissions, and food chain contamination, the size and potential susceptibility of the community within the likely pathways of exposure, the comparison of expected human exposure levels to the short-term and long-term health effects associated with identified hazardous substances and any available recommended exposure or tolerance limits for such hazardous substances, and the comparison of existing morbidity and mortality data on diseases that may be associated with the observed levels of exposure. The Administrator of ATSDR shall use appropriate data, risk assessments, risk evaluations and studies available from the Administrator of EPA."

In accordance with the CERCLA section cited, this Health Assessment has been conducted using available data. Additional Health Assessments may be conducted for this site as more information becomes available.

The conclusions and recommendations presented in this Health Assessment are the result of site specific analyses and are not to be cited or quoted for other health assessments or evaluations.

Foreword

The Agency for Toxic Substances and Disease Registry (ATSDR), was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency (EPA) and the individual states regulated the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from states with which ATSDR has cooperative agreements. Arizona is one of the states in which the Department of Health Services (ADHS) has a cooperative agreement with ATSDR to conduct public health assessments on their behalf.

Exposure: As the first step in the evaluation, ADHS/ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data, but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could have come into contact with hazardous substances, ADHS/ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR/ADHS recognizes that children, because of their play activities and their growing bodies may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR/ADHS considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR/ADHS uses scientific information, which can include the results of medical, toxicological, and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is the case, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk activities), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR/ADHS is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by environmental agencies, or other responsible parties. However, if there is an urgent health threat, ATSDR/ADHS can issue a public health advisory warning people of the danger. ATSDR/ADHS can also instigate health education or pilot studies of health effects, full scale epidemiology investigations, disease registries, surveillance studies or research on specific hazardous substances.

Interactive Process: The health assessment is an interactive process. ATSDR/ADHS solicits and evaluates information from numerous city, state, and federal agencies, the companies responsible for clean up, and the community. It then shares its conclusions with them. Agencies are asked to respond to an early version of the report and to make sure that the data they have provided is accurate and current.

Community: ATSDR/ADHS also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR/ADHS actively gather information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals, and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for inclusion of their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Attention: Chief, Office of Environmental Health
Arizona Department of Health Services
3815 N. Black Canyon Highway
Phoenix, AZ 85015

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1.0 Executive Summary

The objective of this health assessment is to provide an evaluation of the health risks that may result from exposure to abandoned mine tailings in Klondyke, Arizona. The tailings are remnants from an earlier flotation mill and mining operation that was in business from the early 1900's until 1950.

Environmental data indicate that the 70,000 cubic yards (yd^3) of tailings that remain on the property have contaminated the soil and nearby creeks with heavy metals. This report evaluates the potential pathways of human exposure to the contaminated media. The contaminants of concern further evaluated are lead, arsenic, cadmium, mercury, manganese, and boron. Child health issues and community concerns are also an integral part of the evaluation.

Chronic systemic toxicity in adults and children is evaluated using reasonable maximum exposure scenarios based upon reported site usage and observations from site visits. The analysis includes inhalation, ingestion, and dermal absorption of the heavy metals in humans, but does not include terrestrial, or animal uptake. Potential chronic health effects from the tailings are evaluated assuming a transient exposure of six years for children and thirty years for adults. Standard default exposure factors are used when site specific information is unavailable.

The potentially complete routes of exposure to the contaminants of concern are inhalation, ingestion, and dermal contact with soils and dry river bed sediment. The scenarios included in the analysis are camping and the use of all-terrain vehicles (ATVs). The proximity of the site to the Aravaipa Canyon wilderness preserve and the creeks draws hikers and campers to the area. Evidence of the use of ATVs was also observed on the property.

The nearby creeks, into which tailings appear to be eroding, would also draw recreational swimmers and bathers. Dermal absorption and ingestion of surface water from the creeks is also a potential hazard that is evaluated. Fish from the creek may also be consumed by residents and visitors, and thus ingested metals may also be of concern. Once-a-week exposures are assumed for an occasional weekend outing in this scenic area.

The results of the analysis suggest that the site, as it currently exists, does not pose a health risk to nearby residents, campers, swimmers, or ATV users. The consumption of fish from Aravaipa Creek also does not present an apparent adverse health risk. If land use or chemical levels change, a new evaluation will be needed to re-assess potential exposures.

2.0 Purpose and Health Issues

The Arizona Department of Environmental Quality (ADEQ) requested the Arizona Department of Health Services (ADHS) to evaluate all potential health effects posed to a community living alongside Aravaipa Creek near tailings remaining from an abandoned mining operation.

The site first came to the attention of the US Fish and Wildlife Agency because elevated levels of lead and arsenic were detected in area fish during routine monitoring of protected species present in the area. The eroding tailings were thought to be contaminating creek water containing seven different species of native fish, all of which are either threatened or endangered. The point source and monitoring unit staff at ADEQ received this complaint in March of 1993.

The site is currently under preliminary investigation by ADEQ and has been listed as a priority site on the Water Quality Assurance Revolving Fund (WQARF) based on initial sampling results. No cleanup activities are yet under way as the remedial investigation and feasibility study (RI/FS) has not been completed.

The health risks posed to residents in the area by the site were not known prior to this health assessment. The objective of this health assessment is to provide an evaluation of the health risks that may result from exposure to the abandoned mine tailings. All pathways of exposure with potential human contact are being investigated by ADHS to ensure the public health and safety of the residents.

3.0 Background

The town of Klondyke is a rural community of approximately 40 people located along the Aravaipa Creek. The town is approximately 5 miles south of Safford along state highway 70, and is about 100 miles east of Tucson in Aravaipa Canyon. [US Census, 1990]. The tailings are on a private property located 2.1 miles upstream of Stowe Gulch and 1.2 miles downstream of Klondyke in Graham County (see Area and Site Maps in Appendices A and B).

3.1 Site History

The Klondyke area was mined for lead, zinc, copper, molybdenum, silver, and gold from the 1870's to the mid 1900's. The Head Center and Iron Cap Mines were the principal mines in the area [Simons, 1964]. These companies were purchased and consolidated by the Athletic Mining Company in 1942. A floatation mill, constructed later on the site, processed the ore from 1948 to 1950. This milling activity is thought to have produced the Klondyke tailings currently remaining on the bank of the Aravaipa Creek. No further mining operations have occurred on the site since 1950, and the site today remains unchanged. The current owner of the property lives in the neighboring property and has not used the site for any other purpose.

The site contains a water tank tower; two tailings piles; two collapsed structures; miscellaneous machinery; five dilapidated, unoccupied homes; two mine entrances; and an open-air shed used by the owner for storing bales of hay (Appendix D for site photographs]. The site, including the tailings, is classified as a historic property and qualifies for listing in the National Register of Historic Places.

Approximately 70,000 yd^3 of the original 137,638 yd^3 of tailings remain on the site on the east bank of Aravaipa Creek. The tailings are roughly 30 feet away from the edge of the creek. The river channel is a compound system comprised of an inner, low flow channel, and an outer braided channel. In the vicinity of the tailings, the channel is unusually narrow and has a relatively steep gradient, both of which enhance the likelihood of bank erosion in that area. The Aravaipa Creek water becomes cloudy during heavy rain and floods because of erosion of sediments and metals from the mining operations.

3.2 Environmental Sampling Data

Surface Water Samples

Studies done by the Bureau of Land Management (BLM) have found elevated levels of iron in the creek surface water. Additional sampling by ADEQ showed that creek water contained low levels of suspended boron, iron, and manganese, but did not contain any dissolved heavy metals (Table 1). ADEQ reports that there is evidence that the tailings have eroded into the creek with each rainfall. Samples collected at or adjacent to the tailings had a slightly lower pH and a higher total dissolved solids content than those collected upstream or downstream of the tailings.[SCS Engineering Report, 1998].

Table 1: Surface Water Samples *(June 1997)*

Chemical	Level Detected (mg/L)	Detection Limit
Boron	0.14	0.10
Iron	0.16	0.10
Manganese	0.05	0.05

Sediment Samples

Additionally, the levels of metals in the creek sediment adjacent to the tailings had higher levels of metals than those samples taken upstream or downstream. Erosion effects from high flows in the creek in 1993 (peak flow was 13,000 ft^3/sec versus 4,700 ft^3/sec in 1992) resulted in complaints to ADEQ from the US Fish and Wildlife Services. Under a grant from the AZ Department of Water Resources, ADEQ and SCS (a consulting company) engineers began researching a long-term remediation strategy to either remove or stabilize the tailings.

A total of four sediment samples collected in June 1997 by SCS engineers were taken from the top two to six inches of the Aravaipa Creek streambed. Two samples were taken upstream of the tailings piles, while one sample was taken adjacent to the tailings, and one downstream of the piles. Table 2 summarizes the analytes measured, the levels detected, and the soil remediation levels (SRL) for comparison.

***Table 2 : Sediment Samples** (June 1997)*

Sample Location	Contaminant	Level Detected (mg/kg)	SRL (mg/kg)
Aravaipa Creek			
upstream	copper	16	63,000
	lead	40	2,000
	silver	nd (0.1)	8,500
	zinc	74	510,000
adjacent to site	copper	51	63,000
	lead	370	2,000
	silver	0.19	8,500
	zinc	110	510,000
downstream	copper	14	63,000
	lead	31	2,000
	silver	nd (0.1)	8,500
	zinc	54	510,000
Laurel Creek			
upstream	aluminum	not analyzed	1,000,000
	antimony	not analyzed	680
	arsenic	nd (50) **	10
	barium	nd (10)	110,000
	cadmium	nd (10)	850
	copper	120	63,000
	chromium	nd (10)	4,500
	lead	840	2,000
	manganese	950	43,000
	mercury	nd (0.25)	180
	silver	nd (10)	8,500
	zinc	400	510,000
adjacent to site	aluminum	8,000	1,000,000
	antimony	nd (100)	680
	arsenic	nd (100) **	10
	barium	33	110,000
	cadmium	23	850
	copper	2,200	63,000
	chromium	nd (10)	4,500
	lead	10,000 [#]	2,000
	manganese	4,000	43,000
	mercury	nd (0.25)	180
	silver	11	8,500
	zinc	10,000	510,000

** detection limit is higher than SRL (may be an excedence)
[#] : excedence of SRL

Fish Samples

Native fish in the creek include the loach minnow, the spikedace, sonora sucker, desert sucker, speckled dace, longfin dace, and roundtail chub. Also found are the lowland leopard frog. Non-native fish found in the creek include green sunfish, yellow bullhead, and fathead minnow. Most of these fish found in the creek are considered small game fish and are not generally consumed, according to the AZ Fish and Game Department. Moreover, several of the species are endangered and are not permitted to be hunted as game fish.

According to a 1997 US Fish and Wildlife report, levels of arsenic, cadmium, and lead in the fish samples collected in 1997 were above background levels in 36% to 96% of the samples (Table 3). Samples of fish were taken at the schoolhouse area and near the Salazar property approximately 1.5 miles upstream from the wilderness area. Fish were analyzed for arsenic, cadmium, lead, and mercury. Arsenic was detected in 12/14 samples, while cadmium and lead were detected in all 14 fish samples. No mercury was detected.

Table 3: Fish Samples *(October 1997)*

Location	Species of Fish	Contaminant	Level Detected (µg/g)
School house	Sonora sucker	arsenic	0.17
		cadmium	0.29
		lead	4.06
		mercury	ND<0.25
	Desert sucker	arsenic	0.45
		cadmium	0.10
		lead	1.98
		mercury	ND<0.25
Salazar House	Yellow bullhead	arsenic	ND<0.10
		cadmium	0.09
		lead	0.26
		mercury	ND<0.25
	Sonora sucker	arsenic	0.22
		cadmium	0.40
		lead	5.00
		mercury	ND<0.25

Groundwater Samples

Off site, all the area residents rely on private drinking water wells. On site, the only well present was the drinking water and production well from the Athletic mining company's operation. This well is in between the lower tailings pile and the creek . According to the current owner of the property, this

well draws water from 80 to 100 feet below ground level at 250 gallons/minute. This well has been used for irrigation in recent years. [Hyde, 1993].

Groundwater samples were taken both in 1993 and 1997 at various locations on the site. In 1993, two samples were drawn after a major flood from beneath the stream beds when ground water depth was between 4 to 6 feet. An additional sample was also taken from an on-site production well where the depth was less than twenty feet. In 1997, after a long period without any significant storms, another two samples were collected, one at the upper tailings pile and the other at the lower tailings pile at a depth of 60 feet, where the depth to water was 45 feet. [SCS Report, 1997]. Depth to groundwater at the tailings varies between 45 feet during dry seasons to 20 feet during wet months.

Arsenic, barium, beryllium, boron, cadmium, chromium, copper, iron, manganese, nickel, lead, silver, and zinc were analyzed and found to all be less than groundwater protection limits (GPLs) in all streambed and tailings piles samples. GPLs are soil cleanup levels that are protective of groundwater quality that are in ADEQ Administrative Rule. [AAC, Title 18, Ch.7, Article 2]. The samples from the onsite well contained levels of the contaminants less than health based comparison values for all compounds tested. Therefore, groundwater has not been found to be contaminated at levels above screening values, and no drinking water sources are considered impacted at this time.

Soil Samples

Soil on the property has been found to be heavily contaminated with arsenic as high as 280 mg/kg and lead at 54,000 mg/kg on the actual tailings piles, exceeding the Arizona Soil Remediation Levels (SRLs) (Table 4). SRLs are risk-based clean-up standards set by ADHS and included in ADEQ Administrative Rule. [AAC, Title 18, Ch. 7, Article 2, Section R18-7-204]. The cleanup levels reflect the risk posed to human health. They do not consider ecological risks.

Two distinct piles of tailings exist, the upper and lower tailings, named for their relative position along the stream. The lower tailings pile is an L- shaped mound located further downstream than the mill site, with approximate dimensions of 80 X 200 yards. The lower tailings pile was estimated by SCS engineers in June 1997 to contain about 36,000 cubic yards (yd^3). A loading ramp is located on the southern end of the pile with a crusher machine on the east side. Most of the surface is fairly compacted, with the grain size of the tailings being typical of milled ore. The edges of the piles have been eroded by a combination of natural and man-made erosion. Iridescent metals gleam in the dirt and the colors are more solid in certain places, while in other eroded areas the dirt and metal soils appear diluted.

The upper tailings pile is approximately 70 yards upstream of the lower pile, and it is a flatter, rectangular shaped mound with dimensions of 110 X 80 yards. The texture of the soil in the upper pile is a finer consistency than the ore cobbles in the lower pile. The other properties of the upper pile are similar to the lower pile, showing eroded berms and iridescent-colored soil upon inspection.

The tailings piles soil samples averaged 81% solids, with most of the metals present in the oxide form. The leachability of lead, cadmium, copper, manganese, zinc, and beryllium was established by ADEQ by the concentrations in both ponded water found on the tailings piles, as well as shallow subsurface water. The leachability of lead was further confirmed by the toxicity characteristic leaching procedure (TCLP) which resulted in drawing out 1.7 mg/L of lead.

A total of 24 samples were collected by ADEQ in July and October of 1997, from the top 4 to 6 inches of the soil on the tailings areas. See Table 4 for a list of contaminants analyzed in the soil and the levels detected. Lead and arsenic exceeded SRLs and will be further evaluated as contaminants of concern.

Table 4 : Soil Contaminants *(June 1997)*

Contaminant	**Maximum concentration detected** (mg/kg)	**SRL** (mg/kg)	**Chemical of concern**
arsenic	280	10	yes
antimony	130	680	no
barium	170	110,000	no
cadmium	110	850	no
chromium	21	4,500	no
cobalt	24	97,000	no
copper	6400	63,000	no
cyanide	0.27	14,000	no
lead	54,000	2,000	yes
manganese	10,000	43,000	no
mercury	0.41	180	no
nickel	18	34,000	no
silver	18	8,500	no
zinc	33,000	510,000	no

3.3 Data Sampling Methodology

Data sampling and analysis methods were reviewed. Standard quality assurance, quality control procedures (QA/QC) were followed in the analysis of samples at the ADHS laboratory for the soil, sediment, groundwater, and surface water. The location of samples taken, the number of samples taken, and the methods of analysis were reviewed to confirm the applicability of samples for the health exposure assessment. [SCS Report, Appendix E].

Fish samples were collected by US Fish and Wildlife in October 1997, and ADEQ were also analyzed at the ADHS state laboratory using solids reference method EPA 200.3 (arsenic), EPA 200.9 (lead and cadmium), and EPA 600/4-81-055 (mercury).

Tailings samples were taken from the top 2 to 6 inches, and were characterized with an adequate number of samples scattered throughout the site, but mainly concentrated around the tailings piles. The samples were taken by ADEQ in 1993. The tailings samples averaged 81% solids with a pH value of 5.4. In sediment and soil, contaminants of concern were lead and arsenic. Lead was analyzed by a more sensitive graphite furnace technique for lower detection levels as per the request of ADEQ. Lead was analyzed by water reference method EPA 239.2, and solids reference number EPA 3050/6010. Arsenic was analyzed by water reference method EPA 200.7 and solids method reference EPA 3050/6010.

Surface water samples also taken by ADEQ in 1993 and detected magnesium by EPA water reference method EPA 200.7/242.1. Boron and iron were also detected by EPA water method 200.7/236.1. All samples followed standard QA/QC methods and were analyzed by the ADHS state laboratory. Peak flows of the creeks in the area vary greatly and may also affect contaminant concentrations. Annual peak flows at Aravaipa Creek were examined from 1919 to 1994 using data collected by the Bureau of Land Management. The measurements were taken near Mammoth, Arizona, and showed an average peak discharge of 6462 cubic feet per second (ft^3/second) from 1990-1994. However, over the years, the discharge has widely ranged from 70,800 ft^3/second in 1983 to 1,040 ft^3/second released in 1988.

Groundwater samples were analyzed by the ADHS state laboratory in 1993 for alkalinity, chloride, conductivity, hardness, fluoride, sulfate, pH, turbidity, bicarbonate, dissolved and suspended solids, and total recoverable metals, all of which may affect the quality of the sample. No contaminants of concern were detected in groundwater.

3.4 Fate and Transport of Chemicals of Concern

Heavy metals present in soil may be adsorbed to soil particles, they may diffuse through the soil depending on solubility and other soil characteristics, or they may be released into the air as fugitive dust emissions. Adsorption of metal compounds such as arsenic to clays, organic matter, and other oxides generally decreases its mobility. Also, the solubility of the compound may be decreased as metals such as arsenic become encased in silica or bound to soil organic matter, thus concentrating the metals in the upper soil layers. Therefore, the fate of metals in soil are dependent upon soil type, pH, particle size, the amount of metal present, the organic matter content of the soil, the presence of inorganic colloids and iron oxides, and cation exchange capacity.

Transport of metals through water media also depends on the chemical form, the oxidation state, and the interactions with other substances present. Metals in water tend to move from the water to be deposited onto sediments or soils. The amount of lead that remains in solution depends on the pH of the water and the dissolved salt content. In most surface waters, the concentration of dissolved lead tends to be low because the lead tends to form precipitates with anions in the water such as hydroxides, carbonates, sulfates, and phosphates that have low water solubilities. In turn, sediment bound metals may then be re-released by into the water by chemical or biological degradation.

Airborne metals exist primarily as particulate matter less than 2 µm in diameter. The particles are transported by air currents due to wind erosion, or mechanical disturbances of the soil. Particulate re-deposition depends on particle size and meteorological conditions, but the residence time of arsenic in the air tends to be on average nine days. The particles can also then be deposited into surface waters, which may also be a source of water contamination. Arsenic is generally released into the air as arsenic trioxide, or as an arsine. It is unclear how the composition of lead changes through dispersion. [EPA ,1986a].

3.5 Physical Hazards on Site

Aside from the contaminated media, other physical hazards exist on the property. The site perimeter is not completely enclosed in any fencing or restrictive boundaries. The property is accessible from the main road running through Klondyke, along which some fencing exists, and the driveway to the site has a gate that is kept unlocked. The site also has an old schoolhouse located at the far end near the main turnoff road and the driveway to the site. The schoolhouse has not been used for educating children in many years, but is apparently still used for community gatherings.

The property owner lives on an adjacent property. The remaining nearby properties consist of large multi-acre properties with single family homes, and a small general store serving as the local post office, grocery, hardware, and animal feed supply shop. Klondyke Road continues past the town and ends approximately 1.5 miles downstream of Aravaipa Creek in a protected wildlife area called Aravaipa Wilderness Preserve.

The property contains five abandoned buildings, two collapsed structures, a water tank, an open storage shed, scattered debris, and old mining equipment that may draw curious children. The abandoned buildings appear to have been used as residences at one time, but they are in poor condition, with broken glass and large appliances strewn inside. None of the houses are locked, and some contain old, decaying bedding materials, as well as unstable floor boards. Old, rusty mining equipment is also out in the open and may be dangerous for children to play on.

The mine shaft entrances are boarded up with pieces of wood; however, gaps remain between boards, which curious children or adults may be able to pry away and crawl between. Cow droppings litter the property and are evidence that free range cattle are roaming the area.

4.0 DISCUSSION

4.1 Contaminants of Concern

The contaminants of concern (COCs) were selected based upon the concentrations of the contaminants; the quality of the data; the comparison of concentrations of contaminants with background levels; the comparison of concentrations of contaminants with health based comparison values; and finally, based upon community concerns.

The COCs will now be further evaluated based upon a toxicological evaluation and health outcome data in order to determine their public health implications. The contaminants of concern in the tailings soil as well as the river bed sediment are lead and arsenic. In surface water they are boron, iron, and manganese. The contaminants of concern that will be analyzed in fish samples are arsenic, cadmium, mercury, and lead.

Estimates of exposure concentrations and pathway-specific doses are calculated to quantify human exposures to each of the contaminants of concern. Exposure scenarios are determined according to usages of the site. Ingestion, inhalation, and dermal contact will be evaluated when appropriate. The goal of this health assessment is to estimate reasonable maximum human health risks from the site.

4.2 Exposure Pathways

In order to determine the scenarios under which people may be getting exposed to a potentially harmful toxin, a pathway analysis was performed. The analysis involved identifying the source of contamination, the transport of the contaminant through environmental media, an exposure point, a potential route of exposure, and the existence of an receptor population [see Table 5]. Completed pathways in which all of these elements were present were subsequently analyzed more closely to determine the doses at which human exposure may be occurring.

Completed pathways demonstrate the link between the environment and human exposure. A combination of site visits, analysis of land use patterns, and information gathering in the community was used to determine how humans may be coming into contact with contamination in the environment.

Once reasonable exposure pathways were determined, chronic daily intake was quantified in milligrams of chemical per kilogram body weight per day. The chronic daily intake (CDI) is the quantity of a chemical which is available to the body for absorption at a membrane exchange boundary, be it via ingestion, dermal, or inhalation exposure. It is different from the absorbed dose, which is a direct measurement of the concentration of chemical in the blood. Equations 1-6 were used to quantify the daily dose for children and adults given particular exposure scenarios and media. (see Appendix E). When exact data is not available for determining exposure, default assumptions are made based upon EPA exposure factors, and other current data or appropriate models (see Appendix F).

Table 5 : Exposure Pathway Summary

Potential Population Exposed	Exposure Point	Exposure Route	Pathway Quantified ?	Exposure Likelihood	Rationale
ATV using Residents	Soil on tailings piles	Inhalation	Yes	Completed pathway	Off road vehicle tire track marks are visible on the tailings piles and all over the site. These vehicles were seen being commonly used by residents throughout the area
		Ingestion	Yes	Completed pathway	
		Dermal contact	Yes	Completed pathway	
Campers/ Hikers	Soil on tailings piles	Inhalation	Yes	Completed pathway	
		Ingestion	Yes	Completed pathway	
		Dermal	Yes	Completed pathway	
Campers/ Hikers	Sediment from dry river beds	Inhalation Dermal Ingestion	Yes Yes Yes	Completed pathway Completed pathway Completed pathway	River beds are dry 6 months of the year and soil sediment is exposed
Residents	Water from Aravaipa Creek	Ingestion	Yes	Completed pathway	Swimming in the creek; washing cattle in creek
		Dermal	Yes	Completed pathway	
Residents/ Campers	Fish from Creek	Ingestion	Yes	Potential pathway	Recreational Fishing
Residents	Groundwater	Ingestion	No	Unlikely pathway	Wells not contaminated
Residents	Contaminated cattle	Ingestion	No	Unlikely pathway	No animal feed on site
Residents	Fruits and vegetables	Ingestion	No	Unlikely pathway	No edible plants grown on site

4.3 Completed Pathways of Exposure

4.31 All-Terrain Vehicle Users

Inhalation of Dust

Arsenic and lead at this site are not volatile, but they may be released into the air from contaminated soils and dust and respired from either wind or other disturbances of the soil. Inhalation of soil from wind erosion may pose some risk, however, no residents live on the site to be continuously exposed to this relatively small quantity of dirt. The risk from wind erosion will be quantified; however, of greater concern are mechanical disturbances of the soil from people engaging in short-term activities such as dirt bike or all-terrain vehicle (ATV) use that may produce much larger quantities of dust. This recreational exposure will also be assessed since track marks from ATV's were seen upon the tailings piles, and the use of these vehicles in this area seems quite common, as was observed during an ADHS site visit in October of 1998.

Inhalation of nonvolatile chemicals adsorbed to respirable particles (particulate matter 10 microns or PM_{10}) were assessed using a particle emission factor (PEF). The PEF converts a contaminant concentration in soil to a concentration of respirable particles in the air from fugitive dust emissions. The model is derived by Cowherd (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where surface contamination provides a continuous and constant potential for emission over an extended period.

No monitoring data are available on the levels of PM_{10} released during ATV activities, but a value was estimated using a simple emission model [Cowherd, et al, 1985] along with a box model [Hanna, et al, 1982]. Based on the values estimated for ATV use on another similar old mine tailings site, the PM_{10} emission rate was estimated to be 20 micrograms per meter squared-second (ug/m2-sec), and the [PM_{10}] was found to be 380 ug/m3. [Shiefer, et al, 1993]. Under these assumptions, the PEF would be $4.6E^{-9}$ kg/m^3. These values are then applied to the equation for intake from fugitive dust, along with the standard default values for intake rate, to estimate daily intake of soil from this activity.

Residents are estimated to be engaging in ATV activity once a week for 2.5 hours during each ride. Of the time that riders spend in the area, about 25% of the time is assumed to be spent actually riding their ATV's on the tailings piles, whose large, graded slopes are probably attractive to riders, as the track marks on the piles indicate. Due to the temperate climate in Arizona, people may be riding year round, and wearing long sleeves and long pants to minimize injury from a fall. Most of the riders are more likely to be adults since there are few children in the area and our survey indicated that they would not likely be engaging in this activity.

The 70,000 yd^3 of hazardous waste tailings remaining on the site contain concentrations of lead and arsenic exceeding the AZ Soil Remediation Levels (SRLs). All soil and sediment samples were collected and analyzed by EPA methods. [SCS Report, Appendix E]. The samples contain a mean concentration of arsenic of 125 mg/kg, with the upper limit being 280 mg/kg found on the tailings.

The lead concentrations ranged as high as 54,000 mg/kg, with the mean of 12 samples taken on both tailings piles averaging 18,000 mg/kg.

Based on risk of exposure to fugitive dust from adults partaking in ATV activities once a week for a 30-year period, the daily intake of arsenic from inhalation of soil with a concentration of 125 mg/kg for an adult is $7.7E^{-10}$ mg/kg/day. The minimal risk level (MRL) of $3.0E^{-4}$ mg/kg/day is the dose at which humans will not experience health effects, suggesting that ATV users are unlikely to experience adverse health effects from the inhalation of arsenic in tailings.

Exposure to lead at 18,000 mg/kg in the soil would equate to an inhaled adult daily dose of $1.1E^{-7}$ mg/kg/day. The lowest observed adverse effect level (LOAEL) for exposure to lead showing any adverse human health effects, $1.0E^{-2}$ mg/kg/day, is above the daily intake of lead for ATV users, suggesting that ATV users are unlikely to experience adverse health effects from the inhalation of lead in tailings.

Soil Ingestion

Exact intake rates from the ingestion of soil from ATV activities have not been quantified. Unlike ingestion from normal wind erosion, the mechanical disturbance of soil from this activity would expose a person to more concentrated amounts of dust and dirt. The closest comparable rate was the mechanical disturbance of soil in gardening type activities of 480 mg/event.

Typically, it has been assumed that 100% of arsenic that is ingested is bioavailable based on studies using pure salts. [EPA, 1984]. However, this approach is not accurate for evaluating metals from soils, because solid phases are much less soluble. Oxidation reactions on mineral surfaces result in encapsulation of the metal by an insoluble matrix such as silica. Data from bioavailability studies done in Utah and in Anaconda, Montana, using adults suggest a much lower level.

Therefore, all ingested soil and sediment exposures for Klondyke take into consideration a total bioavailability of 18% for adults exposed to lead and arsenic. The estimates for bioavailability used for adults were based upon similar mining type processes during the same time frame on other sites where speciation of the minerals was conducted. [Kennecott NPL Site Bioavailability Study, May 1997].

Adults participating in ATV activities on the tailings piles could ingest $5.8E^{-6}$ mg/kg/day arsenic. The chronic MRL for arsenic is $3.0E^{-4}$ mg/kg/day. Therefore, the ingested amount is much smaller than the dose at which health effects may be seen, suggesting that ATV users are unlikely to experience adverse health effects from the ingestion of arsenic in tailings.

The amount of lead ingested by an adult would be approximately $8.0E^{-4}$ mg/kg/day, which is much lower than the LOAEL of $1.0E^{-2}$ mg/kg/day, suggesting that ATV users are unlikely to experience adverse health effects from the ingestion of lead in tailings.

Dermal Exposure

ATV riders are assumed to be wearing long sleeves and long pants to protect themselves against falls. Their dermal exposure to the contaminants in the soil could be $2.6E^{-7}$ mg/kg/day for arsenic and $3.7E^{-5}$ mg/kg/day for lead based upon the given exposure scenarios. The health based MRL and LOAELs are both higher for arsenic and lead than the estimated dermal daily doses, suggesting that ATV users are unlikely to experience adverse health effects from the skin absorption in tailings.

Integrated Blood Lead Model

ATSDR has developed a model to estimate blood lead levels utilizing regression analysis with multi-route uptake parameters. [Mumtaz, et al., 1985]. The model takes into consideration lead exposure from multiple sources such as lead paint, dust, food, water, and soil, since primary routes of exposure to lead occur via ingestion and inhalation. Bioavailability, age, behavioral factors, and nutritional variables can be adjusted for in this model using various slope factors. Review of the literature for an appropriate slope factor suggested a slope factor of 0.0068±0.00097 for soil exposure based on a study by Angle, et al., done in 1984. [ATSDR Tox Profile:Lead, 1997].

The ATSDR blood lead model, assuming default values for air, food, water and dust intakes, but site-specific concentration-based information on soil concentrations, predicts a blood lead level (BLL) for adult ATV users to be 2.7ug/dL. This predicted level is well below the CDC intervention guideline for adults which is 25 ug/dL, which is the BLL at which health effects are seen. [CDC, 1997].

Total ATV User Exposure

The hazard quotients (HQs) are representative of each individual pathway of exposure for ATV riders. [See Appendix G]. The hazard index (HI), is the sum of all the individual HQ's, and would be representative of total soil exposure from ATV usage from ingestion, inhalation, and dermal exposures. The HI's for both arsenic and lead are less than one, and are $2.0E^{-2}$ and $8.4E^{-2}$, respectively. This indicates that the possibility that people using ATV's may experience adverse health effects from the soil can be eliminated.

4.32 Campers and Hikers

Arsenic and lead which are present in concentrations above the soil remediation levels are of potential concern not only for ATV users but also for residents and visitors who may walk or hike in the area. Because no one currently lives on the site, we conservatively estimate in our assessment scenario that people may come into contact with the soil once a week during a 2.5-hour outing in the area. About 25% of their outing time in the area might be spent around the tailings soil. Also, people in this rural area do not move residences every nine years (standard default factor), so a chronic exposure over 30 years is assumed.

The Aravaipa and Laurel Canyon streams are intermittent streams that run for approximately 6-7 months of the year after heavy rainfall, but remain dry river beds the other half of the year. Annual peak flows in Aravaipa Creek ranged from 20,000 ft^3/sec to 1040 ft^3/sec during the time period from 1919-1994. [SCS Report, Table 9].

Sediment samples were collected from four different areas. The samples were taken from the top 2 to 6 inches of the Aravaipa Creek streambed. Two of the areas sampled were upstream of the tailings piles. One was taken adjacent to the tailings and one sample was pulled downstream of where the tailings were located.

The sediment in the Aravaipa Creek bed was not found to contain levels of any metals analyzed (copper, lead, silver, and zinc) above SRL's. Concentrations of the metals analyzed were the relatively highest adjacent to the tailings, and although they were all lower than the SRL's, lead was present above the GPL (groundwater protection limit) at 290 mg/kg. Samples were not analyzed for arsenic, cadmium, mercury, or any other heavy metals.

Sediment samples were also taken from the top 4 to 6 inches in the Laurel Canyon Creek, which feeds into the Aravaipa Creek. Two areas were sampled: one upstream of the site, and one adjacent to the tailings. Laurel Creek sediments were all below SRL's, except for lead, which at 10,000 mg/kg exceeds the SRL of 2000 mg/kg. However, the arsenic samples were non-detect at a detection limit of 100 mg/kg, which exceeds the SRL of 10 mg/kg by ten-fold. Therefore, both lead and arsenic concentrations were further analyzed. Again, the sediments adjacent to the tailings had higher concentrations of metals than those upstream of the tailings, indicating erosion of the tailings piles into the river bed.

Campers or residents hiking around in the area may be exposed to the soil sediment in the channel for six months of the year when the creek is dry. Based on normal usage of recreational areas, we assumed that adults and children may be exposed to the sediment for one hour a week while digging for the exposed, multi-colored river rocks that may be appealing for rock collectors and children.

Exposure to both tailings soil and river bed sediment were analyzed for campers and hikers. A breakdown of the individual daily doses from soil and sediment are given for inhalation, soil ingestion, and dermal exposure. Ultimately, the total camper exposure from both sources of soil will be additive to give the overall total health risk for campers hiking in the site area.

Inhalation of Fugitive Dust

An adult exposed to soil-containing tailings with an arsenic concentration of 125 mg/kg and a lead concentration of 18,000 mg/kg would be inhaling a dose of $1.6E^{-10}$ mg/kg/day of arsenic and $2.2E^{-8}$ mg/kg of lead. A 15 kg child exposed to that same soil once a week for thirty years would receive a dose of arsenic of $5.6E^{-10}$ mg/kg, and a dose of lead of $7.8E^{-8}$ mg/kg. The dose of lead is below the LOAEL of $1.0E^{-2}$, and the dose of that may be inhaled of arsenic is less than the MRL of $3.0E^{-4}$. The threat of health effects from this pathway alone is not likely based upon the hazard quotients; the intakes are well below the reference doses.

Based on the exposure scenario for sediment, the adults would inhale $3.0E^{-10}$ mg/kg/day of arsenic and $3.0E^{-8}$ mg/kg/day lead. Children would inhale $2.8E^{-9}$ mg/kg/day arsenic, and lead would be inhaled by children for a daily intake of $2.8E^{-7}$ mg/kg. These doses again fall well below the health based MRL for arsenic and below the LOAEL for lead. Therefore, the threat of health effects from this pathway alone is not likely.

Soil Ingestion

No bioavailability studies have been found that contained data on children, and no mineral speciation data collected in Klondyke. Therefore, bioavailability of the metals in adults is again estimated to be 18%, as was found in a similar mine tailings site in Kennecott in which speciation studies were conducted.

Children, whose underdeveloped gastrointestinal systems have been shown to absorb higher amounts of metals, are conservatively assumed to have a bioavailability of 100% for ingested quantities of metals. Inhaled or dermally absorbed metals which directly enter into the bloodstream, unlike digested metals that have to be metabolized before entering the blood, also assume 100% absorption.

For campers or other recreational users being exposed to the tailings, adults would ingest $2.0E^{-7}$ mg/kg arsenic and $2.8E^{-5}$ mg/kg/day lead, based on normal default values for soil intake. Children would ingest $1.0E^{-5}$ mg/kg arsenic and $1.4E^{-3}$ mg/kg lead. The MRL for arsenic ingestion is $3.0E^{-4}$, which is more than the ingested doses; therefore, ingestion is unlikely to pose any health risk. The exposure dose for both children and adults is again higher than the LOAEL for lead ingestion at $1.0E^{-2}$, posing no health threat.

Ingestion of arsenic based upon normal adults daily consumption of sediment of 100 mg/kg, reflects an intake of arsenic of $7.5E^{-8}$ mg/kg and lead of $7.5E^{-6}$ mg/kg over a 30-year exposure. Children, whose normal ingestion of soil is found to be 200 mg/kg, are estimated to intake $1.9E^{-6}$ mg/kg of arsenic, and $1.9E^{-4}$ mg/kg over six years. The MRL for arsenic ingestion is $3.0E^{-4}$, which is less than the ingested doses and is unlikely to pose any health risk. The LOAEL for lead ingestion is $1.0E^{-2}$, again more than the daily dose of lead for both children and adults. Therefore, the relative threat of health effects from this pathway alone is not likely.

Dermal Exposure

We assume that recreational activity and dermal contact with the soil is limited to 25% of the body, including the hands, arms, legs, and head for an average person wearing shorts, a shirt, and shoes on the property. Average 70 kg adults exposed to tailings once a week with an arsenic level of 125 mg/kg and lead at 18,000 mg/kg receive a daily dose of arsenic of $1.2E^{-7}$ mg/kg and a dose of lead of $1.6E^{-5}$ mg/kg. Children weighing 15 kg receive a daily dermal exposure of $2.5E^{-7}$ mg/kg arsenic and $3.4E^{-5}$ mg/kg of lead from the tailings soil. The calculations assume standard default values for ingestion, skin absorption of inorganics, and skin adherence factors.

Adjacent to the tailings piles in the Laurel Creek river bed, arsenic was non-detect, but the detection limit of 100 mg/kg exceeds the SRL. Without exact measurements, the concentration of arsenic is assumed to be 50% of the detection limit. Therefore, an adult visiting the Laurel Creek river bed upstream of the site once a week over thirty years may intake through the skin $4.4E^{-8}$ mg/kg/day of arsenic, while a child in the same vicinity would absorb $9.3E^{-8}$ mg/kg/day. An adult exposed to lead in the sediment would absorb $4.4E^{-6}$ mg/kg/day, while a child would intake $9.2E^{-6}$ mg/kg/day.

The MRL for arsenic absorption is $3.0E^{-4}$. The absorbed dose is lower and is unlikely to pose any health risk in either soil or sediment. The LOAEL for lead absorption is $1.0E^{-2}$, again more than the dose that both children and adults are being exposed to, posing no health threat in either soil or sediment. Therefore, the threat of health effects from these pathways is not likely.

Integrated ATSDR Blood Lead Model

ATSDR has developed a model to estimate blood lead levels (BLL) utilizing regression analysis with multi-route uptake parameters. [Mumtaz, et al., 1985]. The model takes into consideration lead exposure from multiple sources such as lead paint, dust, food, water, and soil, since primary routes of exposure to lead occur via ingestion and inhalation. Bioavailability, age, behavioral factors, and nutritional variables can be adjusted for in this model using various slope factors. Review of the literature for an appropriate slope factor suggested a slope factor of 0.0068±0.00097 for soil exposure based on a study by Angle, et al., done in 1984. [ATSDR Tox Profile:Lead, 1997].

The ATSDR blood lead model, assuming default values for air, food, water and dust intakes, but site- specific concentration based information on soil concentrations, predicts a blood lead level for adult and child campers to be 3.0ug/dL, and 3.3 ug/dL respectively. This predicted level is well below the CDC screening guideline for children ages 0-6 which is 10 ug/dL, which is the BLL at which health effects such as learning and behavioral deficits are seen. [CDC, 1997].

Total Camper Exposure

Total exposure from arsenic in the soil show a hazard index of less than one. Total exposure is estimated from the sum of all the individual hazard quotients reflecting each pathway's contribution to the overall risk of exposure from a given media.

Table 6: Total Intake of Soil Contaminants(mg/kg/day)

	Inhaled Dust	Ingestion	Dermal	MRL/LOAEL
ATV USERS				
As_{adult}	*7.7e-10*	*5.8e-6*	*2.6e-7*	*3e-4*
Pb_{adult}	*1.1e-7*	*8.0e-4*	*3.7e-5*	*1e-2*
CAMPERS				
As_{adult}	*1.6e-10*	*2.0e-7*	*1.2e-7*	*3e-4*
As_{child}	*5.6e-10*	*1.0e-5*	*2.5e-7*	*3e-4*
Pb_{adult}	*2.2e-6*	*2.8e-5*	*1.6e-5*	*1e-2*
Pb_{child}	*7.8e-8*	*1.4e-3*	*3.4e-5*	*1e-2*

The daily intake for campers exposed to the soil and sediment is less than the corresponding health-based guidance levels indicating that no chronic health effects would be expected to be seen from exposure to both soil and sediment in the area based upon current data and scientific literature.

The contribution of ingested contaminants in the soil was the most significant route to the overall hazard of each compound. In children, the dermal component was double the contribution of the inhaled dose because of a child's larger surface area to body weight ratio. In adults, however, the inhaled and dermally absorbed doses are almost equivalent. Nonetheless, the total doses were lower than the health-based guidelines for both arsenic and lead in adults and children, so the risk of health effects from sediment exposure given the realistic scenario of exposure proposed is not likely.

4.33 Recreational River Use

Swimming

In order to determine the uses of the creek, a survey was conducted of the local residents by ADHS in June of 1998. The residents polled indicated that the stream was being used for recreational swimming and cattle washing. Area residents indicated that they did not use the creek for fishing. Since human exposure is the goal of the assessment, cattle washing was not evaluated. Recreational swimming in contaminated water was evaluated since persons may absorb the contaminants dermally and may ingest contaminated water while swimming.

The contaminants detected in the surface water include boron, iron, and manganese. The boron was present at 0.14 ppm, iron was detected at 0.16 ppm, and manganese was found at 0.05 ppm. Iron is an essential mineral for humans and at this level poses no risk to humans. Therefore, the contaminants of concern that are further evaluated are boron and manganese.

The dose calculations assume that 75% of the skin is exposed to the contaminated water during swimming once a week. Also, a default diffusion constant of 10^{-3} centimeters per hour (cm/hr) for inorganic compounds is applied. [EPA RAGS :Dermal, page 5-49] At this level, metals are not well absorbed through the skin.

The dose of boron absorbed through the skin by an adult is calculated to be $2.1E^{-5}$ mg/kg, while the dose of manganese absorbed per swim by an adult would be $7.3E^{-6}$ mg/kg. Children weighing 15 kg would receive a dose of boron of $4.5E^{-5}$ mg/kg, which is less than the intermediate MRL of 0.01mg/kg/day. A dose of $1.6E^{-5}$ mg/kg of manganese would be absorbed, which is less than the no observed adverse effect level (NOAEL) of 0.005 mg/kg/day. There would not be any expected adverse health effects at these doses.

While swimming for approximately 1 hour during 150 days of the year, an adult would be expected to ingest $6.8E^{-6}$ mg/kg boron, and $2.4E^{-6}$ mg/kg manganese. A 15-kg child swimming in the Aravaipa Creek would ingest $3.2E^{-5}$ mg/kg boron and $1.1E^{-5}$ mg/kg of manganese. Again, the MRL for boron is 0.01 mg/kg/day, while the NOAEL for manganese is 0.005 mg/kg/day, which is well above the doses of metals that would be ingested while swimming in the creek.

The total daily dose of each compound from combined dermal and ingested intakes reflects the total risk from that compound. The total daily doses of both boron and manganese are still below the health based guidelines for each compound. Therefore, the relative threat of health effects from swimming in the creek is not likely.

4.4 Potential Pathways of Exposure

4.41 Recreational River Use

Initial sampling done in 1983 by US Fish and Wildlife started the environmental investigation that revealed the potential hazard the tailings piles posed to the neighboring community and the wilderness area. Follow-up surface water samples were taken in Aravaipa Creek by the BLM to determine whether any of the contaminants were affecting the ecosystem and the endangered aquatic species in the area.

Fish Consumption

Several creeks flow near the edge of the tailings property. A flotation mill that operated in the middle of Aravaipa Creek may have contaminated the water and sediment in the creek, which in turn would affect the aquatic life in the creek. Furthermore, as the tailings continue to erode from the piles into both the Aravaipa and Laurel Creeks, the fish in these creeks can ingest contaminants in sediment or surface water, or absorb contaminants from the surface water.

Residents or visitors along Aravaipa Creek are potentially fishing and consuming fish caught from the creek. None of the residents surveyed reported that they fished in the creek, however, only five of the approximately 40 residents responded to the survey. Also, the area draws many weekend visitors due to the wilderness canyon and preserve. Campers and nature lovers visiting on the weekends may also partake in fishing activities and may unknowingly be exposed to contaminated fish.

Native fish in the creek include the loach minnow, the spikedace, sonora sucker, desert sucker, speckled dace, longfin dace, and roundtail chub. Also found are the lowland leopard frog. Non-native fish found in the creek include green sunfish, yellow bullhead, and fathead minnow. Most of these fish found in the creek are considered small for consumption and not game fish generally hunted (sought out), according to the AZ Fish and Game Department. Moreover, several of the species are endangered and are not permitted to be hunted as game fish.

According to a 1997 US Fish and Wildlife report, levels of arsenic, cadmium, and lead in the fish samples collected in 1997 were above background levels in 36% to 96% of the samples (See Table 3). Samples of fish were taken at the school house area and near the Salazar property approximately 1.5 miles upstream from the wilderness area. Fish were analyzed for arsenic, cadmium, lead, and mercury. Arsenic was detected in 12/14 samples, while cadmium and lead were detected in all 14 fish samples. No mercury was detected at the detection limit of 0.25 ug/g.

An intake dose of contaminants in the fish was calculated for adults and children eating fish from the creek once a week over thirty years, assuming a random usage of the creek in the areas sampled. Three species of fish were sampled in two different areas. In the area called "schoolhouse," samples of Sonora sucker and desert sucker were taken. These fish showed the presence of arsenic, cadmium, and lead. Mercury was found to be non-detect, when analyzed to a detection limit of 0.25 ug/g, but since the detection limit is high, we conservatively assumed that mercury may have been present at 50% of the detection limit, or at 0.13 ug/g. The daily intakes for both a 70-kg adult and a 15-kg child were calculated for all species of fish caught in the two areas sampled. (See Table 7.)

Table 7: Intake of Contaminants from Local Fish

Contaminant	**Average [conc] ug/g**	**Adult intake (mg/kg/day)**	**Child intake (mg/kg/day)**	**MRL/LOAEL (mg/kg/day)**
arsenic	*0.22*	*6.1E^{-5}*	*2.9E^{-4}*	*3.0E^{-4}*
cadmium	*0.22*	*6.1E^{-5}*	*2.9E^{-4}*	*5.0E^{-4}*
lead	*2.83*	*7.9E^{-4}*	*3.7E^{-3}*	*1.0E^{-4}*
mercury	*n/d =0.13**	*3.6E^{-5}*	*1.7E^{-4}*	*3.0E^{-4}*

*detection limit was 0.25 ug/g and, therefore, was assumed to be present on average at half of the limit

Consumption of fish contaminated with arsenic, cadmium, or lead at these concentrations will not likely pose any health risk. The threat of health effects from this fish consumption is not likely based upon the hazard quotient, as intakes are well below the reference doses. Biomagnification of metals in aquatic food chains also does not appear to be significant, except in algae and lower invertebrates like oysters. [EPA 1982a, 1983e.]

Despite the fact that the mercury detection limits are high, a conservative estimate that mercury may be present at half the detection limit reveals that the dose both adults and children would be exposed to is less than both the MRL and the RfD. Therefore, it is unlikely that there is any health risk from contaminated fish. Moreover, the fish in the area are protected species and are small for consumption, so it is unlikely that significant human exposure could occur at these levels.

4.5 Incomplete Pathways of Exposure

4.51 Agricultural Uses

Current or future residents may grow fruits or vegetables in the soil contaminated by lead and arsenic. Studies have shown that fruits and vegetables may uptake chemicals and store them in the root systems, or in the edible portions of leafy vegetables.

Terrestrial plants may uptake some heavy metals like arsenic in the root system from the soil or by absorption of airborne metals deposited on the leaves, and certain species may accumulate substantial levels (EPA, 1982a.) However, in the desert terrain where the site is located, no edible plants are grown, and thus intake of contaminants via the plants is not a potential hazard that will be assessed. A heavy growth of mesquite covers virtually all of the creek-side land in the vicinity except for the tailings and mill site.

5.0 Child Health Initiative

The property in which the site is located is currently owned by an adjacent neighbor. The abandoned buildings contain old bedding and appliances, so that at one time people were residing on the land. Currently, there are no occupants or signs of permanent residents, but the lack of fencing on the property makes the area a prime target and potential play area for curious children. Also, the track marks of all-terrain vehicles on the property and tailings indicate that the area is used for recreational purposes.

Teenagers, and young people tend to participate in these activities and they may be more susceptible to exposure from fugitive dust emissions from the heavily contaminated soils. Metals are known to pose a higher risk for children at lower levels due to the heightened sensitivity of developing nervous systems to heavy metal toxicity.

Sub-populations of concern are sensitive receptor populations who may be particularly susceptible to chemical exposure. They may include infants, the elderly, or individuals with respiratory problems depending on the COC's and the nature of the exposures. Exposure points for sensitive receptors often include hospitals, nursing homes, schools, and daycare centers where these populations gather. None of these facilities is present in the area around the site.

Sensitive receptors for exposures to lead have been identified as children ages 0 to 6 years. Children in this age range tend to have increased hand to mouth behavior, and thus ingest more soil than older children and adults. Additionally, their developing nervous systems are more susceptible to adverse effects from lead and other heavy metals.

6.0 Community Health Concerns

A survey was issued at the centrally located general store on June 27, 1998. Of the approximately 40 people dwelling in the rural town of Klondyke, five people answered questions about the site and potential health risks, as well as noting their concerns. See Appendix C for the survey issued by ADHS staff.

Four of the five respondents who completed the survey were male, with the average age of the participants being 56 years. The goal of the survey was to characterize the fish consumption in the area and note the community concerns. Furthermore, ADHS needed to assess the various uses of the creek in order to determine the potential exposure pathways.

Five respondents listed swimming, fishing, and cow washing as the primary uses for the creek. None of the respondents reported consuming the fish caught in the creek, however, visitors to the area who are unaware of the creek's protected status, might inadvertently consume some of the fish. No other specific concerns were noted by the community who responded to the survey.

A public comment period was held from May 14 - June 14, 1999. No community comments were received during this comment period.

7.0 Conclusions

The results of the analysis suggest that the site as it currently exists would be classified as a "no apparent public health hazard" by ATSDR standards. Even though people are being exposed to low levels of heavy metals, chronic exposure at these doses does not pose a health risk to nearby residents, campers, swimmers, or ATV users. If land use or chemical levels change, a new evaluation will be needed to re-assess potential exposures.

The site is partially fenced along the main road, but the lack of restriction along the other boundaries allows access to many physical hazards on the site including abandoned mining equipment, deteriorating housing, and old mine shafts. Children and curious adults wandering into this area may unknowingly encounter some physical hazards in the vicinity.

Additionally, evidence shows that erosion of the tailings piles into the creek areas has begun to occur. The tailings piles are currently about 30 yards away from the edge of the creek, but with continued erosion into the creek, it is only a matter of time before a large influx of heavy metals from the hot spots in the tailings piles enters the creek ecosystem. Until the tailings are remediated or contained, monitoring of the site and the creek may be necessary to continue to ensure the safety of the nearby residents and visitors to the area.

8.0 Recommendations

1. Restrict site boundaries with perimeter fencing and warning signs notifying residents and

visitors of the physical hazards present throughout the property.

2. Continue to monitor the site with annual soil, sediment, surface water, and ground water sampling until remediation activities are completed by ADEQ. Riverbed sediment samples adjacent to tailings piles have higher concentrations of metals, indicating that active erosion processes are occurring; this may pose additional health threats in the future if the tailings are not contained.

9.0 Public Health Action Plan

1. ADHS posted public notices in the Klondyke Country Store and on the agency web page, notifying the community of the public comment period.

2. ADHS will created and distributed site fact sheets and health educational materials informing the community of the assessment results.

3. ADHS will continue to assist ADEQ with environmental health monitoring as new data becomes available.

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10. CERTIFICATION

The Klondyke Tailings Public Health Assessment was prepared by the Arizona Department of Health Services under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with approved methodology and procedures existing at the time the public health assessment was initiated.

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The Division of Health Assessment and Consultation, ATSDR, has reviewed this public health assessment and concurs with its findings.

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12.0 Appendices

Results of the Agency and Public Comment Periods:

No comments were received during the agency or public comment periods for the Klondyke Health Assessment. The public comment period for the Klondyke Health Assessment ended June 14, 1999. A press release announcement the public comment period was sent out to various media May 19, 1999. The press release is attached. In addition, Will Humble gave a radio interview for a Tucson radio station to describe the results of the Klondyke Health Assessment.

Appendix A	Klondyke/Safford Area Map
Appendix B	Klondyke Mine Tailings Site Map
Appendix C	Klondyke Community Survey
Appendix D	Site Photographs
Appendix E	Chronic Daily Intake Formulas
Appendix F	Standard Default Exposure Factors
Appendix G	Exposure and Risk Calculations for Contaminants of Concern (COCs)